RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

VOLUME XVIII.

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ERRATUM.

Page 32, line 3 of Analysis, for *alumina and magnesia* read *alumina and oxide of manganese.*

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1885. **[February.**

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1884.

Billa Surgam Caves: *Mr. Foote.*

The Peninsula area.—In Southern India Mr. Foote began the season's work in continuation of the cave exploration in the Karnul District, but in the middle of it he was called upon to undertake an exploration for coal along an intended line of railway between Hyderabad and the Kistna. Fortunately we were able to secure the services of his son, Lieutenant H. B. Foote, R.A., who had been for some time helping his father as an amateur cave-hunter. An interesting preliminary account of the result is published in the last number of the Records. It is on the whole encouraging; a large number of bones have been secured, some of animals that do not now inhabit this region, some human remains and articles of human manufacture, the latter at the considerable depth of 16 feet, but nothing to show that the caves had ever been used as dwellings or as a place of sepulture. Arrangements have been sanctioned for carrying on the work during the present season, after which a close examination of the whole collections should determine whether the search is worth continuing.

Fruitless search for coal in Hyderabad.

The country between Bezváda and the Singareni coal-field, and from the latter to Hyderabad, where Mr. Foote was sent to look for coal, proved, as we expected, to be all of gneissic rocks. The only reward for his labour was the discovery of a strong lode of rich iron ore close to the Singareni coal-field. An account of the traverse is published in the current number of the Records.

Chhattisgarh coal-fields: *Dr. King.*

As stated in last year's report, Dr. King took up work in the series of coal-fields on the north-east confines of Chhattisgarh, especially with a view to exploration for coal near the line of the projected Nagpur-Bengal Railway. The results of his

survey are published in the Records (XVII, part 3). It would be impossible to give any further opinion on the measures until some trial borings have been made; they are now being sunk under Dr. King's direction.

THE REWAH COAL-FIELDS: *Mr. Hughes.*

The promises made in last year's report regarding the Rewah coal-fields have been most successfully accomplished. The shafts put down on the coal in the Umaria field under Mr. Hughes' direction have fully satisfied his expectations, and energetic steps are now being taken under Mr. Hughes' management to establish an extensive colliery there; and a branch railway from Katni on the Jabalpur line is under construction. Mr. Hughes' whole service (since 1862) has been spent on the Gondwana rocks, and it is most pleasing and appropriate that so fruitful a practical result should be in a very special manner due to his sagacity and perseverance. During last season Mr. Hughes also managed to complete the examination of the southern coal-fields of the Rewah Gondwána basin. The total area of exposed coal measures is no less than 1,800 square miles. The descriptive memoir with maps is now in the press.

Mr. Jones joined Mr. Hughes in January. He has this season been deputed to survey the Pench coal-field on the south side of the Sátpura basin.

Sub-Assistant Hira Lál gave satisfactory aid to Mr. Hughes in his survey operations. He has now been transferred to Dr. King.

LOWER VINDHYANS, CHHATTISGARH: *Mr. Bose.*

In the past season Mr. Bose took up new ground, in the basin of the upper Máhánadi. He covered a large area, but I regret to say the result is exceedingly unsatisfactory. For his work in Nimár there was an excellent sketch survey by Mr. Blanford to start with, and the rocks presented no structural complications; Mr. Bose has moreover such facility in expressing himself and in setting up a description that there was little or no room for the detection of error from a perusal of his report, beyond such general defect of scientific insight as I have noticed in the Preface to Mr. Fedden's Kattywar report (Memoirs, XXI, part 2). In Chhattisgarh, Mr. Bose had to break ground for himself; and although this is by no means complicated, his attempt even to understand the problem of the rocks is extremely feeble; his map is no more than a lithological index; there is a total absence of critical observation. In discussing the question of the employment of natives on the Geological Survey of India, I have had frequent occasions to point out that our work is essentially scientific research and does not admit of being done by rule, with little or no understanding; and that if not within measurable range of modern scientific standards it is worthless; on the other hand I mentioned the fact that as yet no single instance had occurred of a native showing himself capable of original scientific work, the conclusion being that the Geological Survey was about the only branch of the public service in which natives could not as yet reasonably find employment. I fear that Mr. Bose is no exception to this rule, although he has had the advantage of the best teaching in the scientific schools of England. It is quite a Darwinian puzzle.

Sub-Assistant Kishen Singh mapped a considerable area of Vindhyan rocks south of Búndi in Rájputána, but it would be impossible to make out a presentable description of the country from his notes.

The extra-Peninsula area.—Mr. Oldham has sent in full progress reports of last season's work in the Himalayan region, embracing a section from the plains to the base of the main range. In the Sub-Himalayan zone the following interesting points have been fixed: the re-discovery of one of Colonel Cautley's most important localities for fossils, at the entrance to the Kalawala Pass (Records, 1884, p. 78); the detection of an unconformity in the upper Siwalik strata east of the Ganges (Records, 1884, p. 161), which later in the season he traced in the range west of the Ganges; but chiefly there has to be noticed a judgment upon the 'main boundary,' that of the old rocks at the inner edge of the tertiary zone. This has been a very burning question, as may be seen by reference to Mr. Theobald's paper on the Siwaliks (Records, XIV, p. 105); but since the correction by Mr. Oldham in 1881 of a certain "key section" near Náhan (Records, XIV, p. 173) the particular view taken by me of the main boundary has lost its chief support, and the view now offered cannot be forcibly contested. The point is discussed with reference to the section in the Nún stream under Mussooree. In the original description of that section in 1864 (Memoirs, III, 2, p. 128) it is left very much an open question whether all the rocks there are not Siwaliks, as Mr. Theobald (*l.c.*) subsequently asserted them to be, and as Mr. Oldham now re-affirms. As regards the main boundary, the 'key' aforesaid made it a very plausible supposition that this feature was an original contact, albeit much disguised by subsequent compression and faulting, whereas Mr. Oldham, by showing inversion of the inner rocks at the boundary, and other fair arguments, makes out the boundary to be a faulted synclinal flexure; though it does not appear that he supposes the original limit of the Siwalik rocks to have been far north of the actual boundary, so that the change of view is not so great as it might seem. When the feature was first discussed the choice seemed to lie between the view then taken and sheer faulting (including under this term the reversed faulting along oblique plains of fracture in the axes of folded flexures); Mr. Oldham also rejects the reversed fault, in its plain form, on account of the absence of the crushing that presumably must occur, and adopts "the supposition of a faulted synclinal flexure in which the disturbance of the original relations has taken place mainly by the older rocks being pushed up over the newer, according to Professor Heim's theory, rather than by an actual shifting of the opposite faces of a fissure." The distinction, in words, is not obvious; and it is very difficult to imagine the process, seeing that the rocks on either side of the dividing plain retain their respective structures; but somehow such contacts *are* brought about with little or none of the grinding action that would seem inevitable. Another very interesting point is the discovery of an outlier of Siwalik sandstone resting on crumpled slates in a low hill north-east of Dehra. With the single exception of a case noticed by Mr. Mallet in the Bhután Duárs (Memoirs, XI, p. 44) it is the only observation of a base-rock within the true Sub-Himalayan zone. The absence of any older tertiary beds here is particularly interesting, as almost necessarily implying their extensive upheaval and removal before the Siwalik period.

OUTER HIMÁLAYA: *Mr. Oldham.*

Among the vastly more complex rocks of the higher hills the changes introduced are more extensive. The series of formations described in Jaunsár (Records

XVI, p. 193) is somewhat altered and greatly amplified, and brought into relation with those of the Simla region. The following is Mr. Oldham's summary of conclusions :—

1.—That the Simla and Jaunsár sections are not related to each other, but that except for some possible exposures of the Krol in Jaunsár the rocks on either have no representative on the other.

2.—That the Simla section does not represent a conformable sequence, but that between the infra-Krol and the Blaini there are interposed (elsewhere) at least two formations, and two unconformable breaks.

3.—That the Deoban and Krol limestones are not the same, but that the former is much older than the latter.

4.—That the Mandháli series is older than the infra-Krol (but newer than the Deoban).

5.—That the Deoban limestone is newer than the Blaini.

6.—That the Blaini is newer than the lower-Chakráta.

7.—That the series which last year were provisionally and doubtfully grouped together as Lower and Upper Chakrátas must be separated as belonging to different formations.

8.—That the Báwars are but a special form of the basement beds of the infra-Krol.

9.—That the Panjál conglomerate occurs in this region, and it is *not* the representative of the Blaini.

It would be unreasonable to expect that all these announcements should be immutable; Mr. Oldham is certainly right in attempting free-hand tentative groupings, and all are based upon local evidence of variable validity.

Those acquainted with it will be glad to see that the primitive series of the Simla section is not much interfered with at home. The Krol limestone, Krol quartzite, and infra-Krol carbonaceous shales still retain the highest groups of the lower Himalayan rock series; and the several groups (Báwar, Mandháli, and Deoban) separating them from their constant neighbour of the Blaini stream are not said to occur here. The discovery of a second conglomerate will greatly reduce the duties of the hitherto seemingly ubiquitous Blaini; and a second strong limestone band to take the place of the Krol in certain places, as in the Sháli mountain north of Simla, is distinctly a relief. Mr. Oldham gives ample stratigraphical observation to confirm Colonel McMahon's petrological arguments that the 'central gneiss' of the Chor and some other places is truly a granite; still I find a 'central gneiss' at the base of the new table of formations; and this too is satisfactory; it would be almost preternatural that such an immense file of geological records should have no archæan foundation. It is lamentable to have to record that still not even the ghost of a fossil has been seen in these rocks.

I have given Mr. Oldham's results somewhat at length, because they may not be immediately published in original, the exigencies of our Indian service having made it desirable to depute him for the current field season to the Andamans with the Topographical Survey party, for which special arrangements have been made, and such an opportunity might not occur again in our time. Mr. Oldham's experience in Manipur (Memoirs, Vol. XIX) at the starting point of this region

of disturbance, may give him some clue to the correlation of the rocks in those island outliers.

Mr. Middlemiss joined Mr. Oldham in January; he has this year been started on independent work in Garhwal.

Colonel McMahon.

Colonel McMahon has now completed his elaborate microscopical studies of a large series of Himalayan rocks, proving among other interesting results the eruptive character of certain pseudo-gneissic rocks of the Dhuladhár, the Chor, and other localities. Mr. Oldham's recent determination of the undoubtedly intrusive relations of this rock in the Chor is a satisfactory conclusion of this enquiry. Colonel McMahon's description (Vol. XVII, p. 104) of the extreme metamorphism, amounting to proximate fusion, of the quartzites of the ridge at Delhi, is an interesting indication upon the history of the Arvali rocks.

HIMALAYAN MOUNTAIN SYSTEM: *Lt.-Col. Godwin-Austen.*

In connection with Himalayan geology it is not out of place to notice a study of the mountain system of the Himalaya presented in Colonel Godwin-Austen's address as President of Geographical Section of the British Association Meeting of 1883, supplemented by a map and sections with notes published by the Royal Geographical Society (Proceedings, 1883, p. 610). If the views given had been mere geographical delineations they would not have called for attention, as being suitable to the audiences addressed; but the essay is a laudable attempt to forestall time by introducing to topographers rational conceptions of mountain structure, and thus geology is necessarily introduced. Unfortunately, however, the author is not himself quite emancipated from the ideas he would subvert. These may be indicated as a mistaken conception of unity based upon an unnatural assumption of continuity. Of this kind is the extension of the extinct axes of the Himalayan range into connection with the gneissic mass of Afghanistan. The confusion is the same as it would be to ignore the separate members of a compound organism; there may be homology, but the forced continuity leaves out of count conspicuous and essential structural characters. Again, to make the Pir Panjál and the Dhuladhár continuous with the Chor mountain of the Simla region, is about the same as it would be to confound the tail of a vertebrate animal with its limbs. These errors have been pointed out before (Records, XV, p. 6).

THE CENTRAL HIMALAYA: *Mr. Griesbach.*

In last year's report I mentioned the completion of Mr. Griesbach's rapid survey of the Hundes region, and that his observations there had been connected with those of Stoliczka in Spiti. I had then to explain the postponement of any fuller notice of the work owing to Mr. Griesbach's urgent deputation to accompany the expedition to the Takht-i-Sulemán. Subsequently to this, while making some connecting observations on the North-West Frontier, he was taken seriously ill at Kohát, in consequence of which it was necessary that he should spend the hot season in the hills, and while at Simla, he managed to get appointed to accompany the Afghan Boundary Commission. Had I been in India, I should probably have succeeded in having some other officer deputed for this duty. No doubt the best use that can be made of Mr. Griesbach is for the superficial kind

of work that is alone possible in those expeditions, and his admirable skill in drawing is a special qualification for such work, nevertheless the further postponement of the account of his Himalayan observations, begun in 1879, should have been avoided. His maps were fully prepared before he left, and are now being reproduced for publication; a large number of illustrations are also ready, but the descriptive text has not yet been sent in, and it cannot be fitly prepared away from sources of reference.

THE TAKHT-I-SULEMÁN.

The details of Mr. Griesbach's observations in the Sulemán hills have recently been published (Volume XVII, part 4). They give fresh illustration of Mr. Blanford's remarks regarding the great variability of the cretaceous and eocene deposits of that region. As regards the newer formations two unexpected points are noteworthy. The object of Mr. Blanford's last exploration on that frontier had been to connect the tertiary series of Sind, which he had so carefully worked out, with the tertiary series of the Sub-Himalayan region; and although an actual tie with previous work to the north was not effected, it was thought, as stated in my last annual report (Vol. XVII, page 7) that the main object had been attained, for in the northern part of his ground, on the flanks of the Sulemán, Mr. Blanford found established a section that fairly represented that known to the north—the marine eocenes surmounted by the neogene Nari and Siwalik groups, believed to be fresh-water deposits, and all in apparent conformable sequence, the two marine groups, lower Nari and Gáj of Sind, having disappeared (Memoirs XX, page 159, *et seq.*). This conclusion is however apparently upset by Mr. Griesbach's observations in the intervening ground to the north: a sandstone full of marine fossils is confidently identified (*l. c.*, page 189) with Mr. Blanford's upper Nari sandstone, and the upper tertiaries are only represented by the Siwalik conglomerates resting in total unconformity on the lower tertiary marine beds. It is very unsatisfactory that Mr. Griesbach does not himself notice these discrepancies, as is usual in such cases to give some sign that he was aware of their importance; he had a proof copy of Mr. Blanford's report with him in the field.

THE ANDAMANS: *Mr. Mallet.*

Some ores, especially a chromite, received from the Andamans, and the accounts sent with them, made it desirable to have a professional opinion upon the deposits. Mr. Mallet was deputed for this purpose, and the result of his examination is published in the Records (XVII, part 2). The block from which the specimen of chromite had been taken could not be traced to any mass *in situ;* and as this mineral in minute crystalline grains was found disseminated in the serpentinous rock of the neighbourhood, it may be presumed that the large block was only a local segregation. An opportunity occurred for Mr. Mallet to visit Barren Island and Narcondam. His account of these interesting volcanic sites is now ready for press.

AKA HILLS AND LANGRIN COAL-FIELD. *Mr. LaTouche.*

Early in the season Mr. LaTouche accompanied the expedition into the Aka Hills, north of Tezpur, in Assam. The dense vegetation prevented any observation of the rocks except in the stream courses. The section was found to correspond with that observed in the Daphla Hills to the east by Colonel Godwin-Austen, and

as described by Mr. Mallet in the Bhután Duárs to the west. Inside the tertiary zone there is a belt of carboniferous Damuda strata, bordering the schistose rocks of the higher hills. Here, too, the coal is so crushed as to be unserviceable. There was some little delay in the preparation of a map; it will be published shortly with Mr. LaTouche's notes. Later in the season Mr. LaTouche examined the Langrin coal-field on the south-west edge of the Gáro Hills. His report with a map is published in the Records (XVII, part 3). This field offers an abundant supply of very fair coal easily accessible on the very borders of the plain of Sylhet.

THE HOMOTAXIS OF INDIAN FORMATIONS; *Mr. W. T. Blanford.*

A very instructive discussion of geological homotaxis is given by Mr. W. T. Blanford in his address as President to the Geological Section of the British Association in its last meeting at Montreal. It is mainly illustrated from Indian geology, and is so important a contribution to this subject that it has been reprinted in the current number of the Records. Numerous instances are given of the discrepancies that occur in the correlations of rocks as based upon their terrestrial fauna and flora, or upon a marine fauna, the latter giving much more comparable results. The former of course maintain all their special interest, but it is very necessary to know upon which kind of evidence the correlation of any strata had been based. Mr. Blanford would somewhat modify the significance of the term homotaxis as introduced by Professor Huxley in 1862. That was, to give expression to the following statement:—"For anything that geology or palæontology is able to show to the contrary, a Devonian fauna and flora in the British Islands may have been contemporaneous with Silurian life in North America, and with a Carboniferous fauna and flora in Africa."[1] These terms of course included the marine fauna; but while granting such conditions to be possible for a terrestrial fauna or flora, Mr. Blanford considers that the marine fauna would give a much nearer approximation to synchrony. He says:—"It appears to me that at the present day the difference between the land faunas of different parts of the world is so vastly greater than that between marine faunas that if both were fossilised, whilst there would be but little difficulty in recognising different marine deposits as of like age from their organic remains, terrestrial and fresh-water beds would in all probability be referred to widely differing epochs, and that some would be more probably classed with those of a past period than with others of the present time."

Mr. Oldham.

The same subject of homotaxis is discussed by Mr. Oldham in the Journal of the Asiatic Society of Bengal for 1884 (Part II, p. 187). He illustrates from our Indian palæontological researches the highly discrepant results of correlations in time from fossil evidence, specially the palæobotanical, and the insuperable failure of any approach to determination of synchrony among distant formations. This is introductory to an attempt to establish synchronous relations of distant formations through the evidence of periods of glaciation, the ground chosen being the same, as containing well-known boulder deposits, the Talchirs of India, the Hawkesbury beds of Australia,

[1] Quar. Jour., Geol. Soc., Vol. XVIII, p. xlvi.

and the Karoo boulder bed of South Africa. Such a distribution of presumably synchronous glaciation, Mr. Oldham suggests, "points towards the conclusion that in early secondary times the crust of the earth did not occupy the same position with respect to the axis of rotation as it does now." The contention is well supported by arguments needed to account for the distribution of the cognate terrestrial fossil fauna and flora of the regions in question. Some years ago a suggestion was made to use the last glacial period as a geological chronometer to fix the age of the Indian post-tertiary deposits; and then too the proposal was elicited by a flagrant abuse of the homotaxis method of correlation, losing sight of the actual in the relative (*supra*, Vol. VII, p. 97, note).

Publications.—Two Memoirs were published during the year—Mr. Bose's on the Lower Narbada Valley between Nimáwar and Káwant, and Mr. Fedden's on Káthiáwár, each with a map of the country described. They form parts 1 and 2 of Volume XXI. The work was contemporaneously noticed in previous annual reports, and some general remarks on both will be found in the preface to the part 2, part 1 having been fully printed off before I returned from leave.

The Records for the year contain numerous articles of interest, several of which have been referred to above.

In the Palæontologia Indica, five parts of series X, the Indian Tertiary and Post-Tertiary Vertebrata, by Mr. Lydekker, were published during the year. They form a very worthy addition to this most valuable part of our publications. For the general advancement of geological science, palæontological researches are certainly the most interesting and important, and at present they are inadequately provided for in the allotment of our resources. It would be impossible for one palæontologist to overtake all the work on our undescribed collections of fossils, even if one man could do justice to so wide a range of studies. I hope to be able to effect a temporary diversion of some funds to bring up arrears of work in this branch of our business.

In continuation of his work on the fossils of the Salt-Range, Dr. Waagen furnished last year two parts (Nos. 3 and 4) of the Brachiopoda of the Productus-Limestone. They exhibit the same exhaustive study as heretofore. To the superficial criticism of some naturalists, Dr. Waagen might seem to lay himself open on the score of minute specific distinctions, but he abundantly justifies his method on biological and palæontological grounds. No doubt, as he says himself, more abundant material may lead to the modification of his grouping, but there is a strong presumption that the principle will hold good. However one might be satisfied for purely biological results to exhibit the links of variation in a few developmental sequences of species and genera, geological history will require the process to be applied throughout. Dr. Waagen gives numerous instances in which those slightly distinguishable forms are characteristic of different stratigraphical horizons. His final discussion of the fauna of the Productus-Limestone should form an interesting chapter on the vexed question of homotaxis.

A large fasciculus of Series XIV, with eighteen admirably-executed plates, was issued early in the year. For this series, descriptive of the tertiary and upper-cretaceous fossils of Sind, taken up four years ago, we are so far indebted to the generous labours of Professor Martin Duncan, latterly aided by Mr. Percy Sladen.

It is the beginning of what must one day become the most extensive part of the Palæontologia, that dealing with the tertiary marine fauna, and the most interesting as more fully bearing upon the living fauna of the Indian seas.

Museum.—As specified in the Records for May, several contributions of ores, rocks, and other geological specimens were obtained from the International Exhibition held in Calcutta early in this year. The principal presentations were from the Minister for Mines, New South Wales; the Minister for Mines, Victoria; and the Tasmanian Commissioner. Some of these were in return for Indian geological specimens previously sent to Australian Museums by the Survey, and for the rest a proper return was made on the occasion.

Library.—The additions to the library were 1,608 volumes or parts of volumes, 742 by purchase and 866 by donation or exchange. The printing of the Catalogue was just completed within the year, for which accomplishment I have again to express obligation to the conscientious industry of our librarian, Mr. W. R. Bion, for thoroughly checking the entries and correcting the proofs. Excepting books received after passing the sheets of the Catalogue for press, the following figures represent a rough inventory of our library at this date: total volumes, 13,205; of which 9,236 come under the heading of Serials, including the publications of Societies, as well as Magazines and official reports; of the remaining 3,969, 1,015 are marked in the Catalogue as pamphlets.

Personnel.—Dr. Feistmantel was absent throughout the year. Mr. Hacket returned from furlough on the 18th of November and resumed his field work in Rájputána. Mr. Medlicott was absent on special leave for six months, during which time Dr. King acted as Superintendent of the Survey. Mr. Mallet took six months' furlough from May to October, during which time Mr. Fedden officiated as Curator of the Museum.

H. B. MEDLICOTT,
Superintendent, Geological Survey of India.

CALCUTTA,
The 20th January 1885.

List of Societies and other Institutions from which Publications have been received in donation or exchange, for the Library of the Geological Survey of India, during the year 1884.

AMSTERDAM.—Netherlands Colonial Department.
BASEL.—Natural History Society.
BATAVIA.—Batavian Society of Arts and Sciences.
,, Director of Instruction.
BERLIN.—German Geological Society.
,, Royal Prussian Academy of Science.
BOLOGNA.—Academy of Sciences.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
BOSTON.—American Academy of Arts and Sciences.
,, Society of Natural History.
BRISBANE.—Royal Society of Queensland.

BRISTOL.—Bristol Museum.
" Bristol Naturalists' Society.
BRUSSELS.—Geological Society of Belgium.
" Royal Geographical Society of Belgium.
" Royal Malacological Society.
" Royal Natural History Museum of Belgium.
BUDAPEST.—Royal Geological Institute, Hungary.
BUENOS AIRES.—National Academy of Sciences.
BUFFALO.—Society of Natural Sciences.
CALCUTTA.—Agricultural and Horticultural Society.
" Asiatic Society of Bengal.
" Meteorological Department, Government of India.
" Survey of India.
CAMBRIDGE.—Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CASSEL.—Society of Natural History.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
Norwegische Comm. der Europäischen Gradmessung.
Royal University of Norway.
COPENHAGEN.—Royal Danish Academy.
DEHRA DUN.—Great Trigonometrical Survey of India.
DRESDEN.—Isis Society.
EDINBURGH.—Royal Scottish Society of Arts.
GLASGOW.—Geological Society.
" Glasgow University.
" Philosophical Society.
GÖTTINGEN.—Royal Society.
HALLE.—Leopoldino Academy.
" Natural History Society.
HOBART TOWN.—Royal Society of Tasmania.
KÖNIGSBURG.—Physikalisch-ökonomische Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Science.
LIVERPOOL.—Geological Society.
" Literary and Philosophical Society.
LONDON.—Geological Society.
" Iron and Steel Institute.
" Journal of Science.
" Linnean Society.
" Royal Asiatic Society of Great Britain and Ireland.
" Royal Geographical Society.
" Royal Institute of Great Britain.
" Royal Society.
" Society of Arts.
" Zoological Society.
MADISON.—Superintendent, Public Property.

MADRAS.—Meteorological Department.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
" Literary and Philosophical Society.
MELBOURNE.—Department of Mines and Water Supply, Victoria.
" Geological Survey of Victoria.
" Royal Society of Victoria.
MILAN.—Italian Society of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
" Royal Society of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—American Journal of Science.
PARIS.—Geological Society of France.
" Mining Department.
PENZANCE.—Royal Geological Society of Cornwall.
PERTH.—Commissioner of Crown Lands.
PHILADELPHIA.—Academy of Natural Sciences.
" American Philosophical Society.
" Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
ROME.—Camera dei Deputati.
" R. Accademia dei Lincei.
" Royal Geological Commission of Italy.
ROORKEE.—Thomason College of Civil Engineering.
SACRAMENTO.—California State Mining Bureau.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
" Imperial Academy of Sciences.
SALEM, MASS.—American Association for the Advancement of Science.
" Essex Institute.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—North China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
SPRINGFIELD.—Geological Survey of Illinois.
" Illinois State Museum of Natural History.
STOCKHOLM.—Geological Survey of Sweden.
STRASBURG.—Royal University Library.
SYDNEY.—Australian Museum.
" Department of Mines, New South Wales.
" Royal Society of New South Wales.
TOKIO.—Seismological Society of Japan.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VENICE.—Royal Institute of Science.

VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
WASHINGTON.—Philosophical Society.
„ Smithsonian Institute.
„ United States Geological Survey.
WELLINGTON.—Colonian Museum.
„ Geological Survey of New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.

The Secretary of State for India.

The Governments of Bengal, Bombay, Madras, North-Western Provinces and Oudh, and the Punjab.

Chief Commissioners of Assam, British Burma, and Central Provinces.

The Commissioner of Northern India Salt Revenue.

The Resident at Hyderabad.

The Comptroller of Indian Treasuries.

The Superintendent of Government Printing, India.

The Superintendent of the Government Central Museum, Madras.

Departments of Finance and Commerce, Foreign, Home, and Revenue and Agriculture.

Notes on the Country *between the* Singareni Coal-field *and the* Kistna River *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a map).

The immediate opening up of the Singareni coal-field having been under consideration by the Government of India, I was deputed to examine the unsurveyed country in the valley of the Munièru (Moonyair) river in the hope of finding further outliers of the Barakar rocks, the Indian carboniferous series, between the Singareni coal-field and Bezwada, as the existence of other coal-fields might greatly influence the selection of the line of country to be traversed by the railway to connect the Singareni coal-field with Bezwada, the central point in the great canal system connecting the whole of the Godavari and Kistna deltas with Madras, and the terminus of the new Bellary-Kistna State Railway.

Limits of area here reported on.

The limits of the previously unsurveyed tract which I examined in carrying out this duty are, to the south the Kistna river; to the west the boundary of the Kadapa rocks, and further north the left bank of the Munièru; to the east a line coinciding with the eastern edge of Atlas-sheet 75; to the north a line running from the Munièru eastward to the edge of sheet 75 a little to the southward of Khammamett. To the north of this line lies a considerable tract extending up to the Singareni coal-field which had been partly examined by Mr. King and of which I completed the survey.

The geological formations met within the area thus defined belong to the following four divisions:—I. *The Gneissic rocks;* II. *The Kadapa* or *Transition rocks;* III. *The River Alluvia;* IV. *Subaerial Formations and Soils.*

Geological formations met with.

I.—*The Gneissic Rocks.*

As will be seen from the map, the gneissic rocks of the Munièru (Moonyair) valley are extensions of the great granitoid and schistose bands seen south of the Kistna river and shown in the little sketch map given in my memoir on the geological structure of the eastern coast.[1]

Disposition of the gneissic rocks.

The gneiss rocks of the Kistna district show two great bands of granitoid rock divided in the southern part of the area by a much narrower band of schistose beds. In the northern part of the area, however, the schistose beds extend considerably to the eastward whereby the eastern granitoid band is interrupted and apparently overlaid by this eastward extension of the schists. Whether this overlapping of the schistose beds over the granitoid really takes place or not, has not as yet been proved, but as it is believed on fair grounds to take place in the southern parts of these great bands in the Nellore district, it may for the present be assumed also to take place in the Munièru valley, and the separate patches of granitoid gneiss lying to the northward of the continuous band may *pro. tem.* be treated as inliers in the schistose area. The two granitoid bands and the intermediate schistose band have to the south of the Kistna a general strike from south-west-by-south to north-east-by-north, which continues till they cross that river and then commences to trend to due north and then to north-north-west. In the neighbourhood of the Singareni coal-field the strike becomes less constant for a distance of 4 or 5 miles, but then trends north-5°-east and continues so till the edge of the overlying Kadapa and Gondwana rocks.

The eastern of the two granitoid bands forms the mass of the very picturesque Kondapalli (Condapilly) hills, as also the broad plain stretching from the foot of the hills past Juzzur (Joodjoor) westward nearly to the east bank of the Wyra river. To the northward the granitoid rocks extend under the alluvium of the Gumplagudum stream (the principal tributary of the Wyra) and run north and north-west-by-north for another 9 or 10 miles, when it is cut off by the east extension (? overlapping) of the schistose rocks above referred to. North of this spread of schistose rock, at a distance of between 4 and 5 miles, lies the first of the inliers also referred to above. It is of elongated elliptical form (in plan), and extends some 12 or 14 miles to the north-west-by-north with a maximum breadth of 5 miles in its southern half. The apices of the ellipse are rather pointed. By far the greater part of its area lies on the western side of the Wyra river. For convenience of reference it may be called the Gollapudi inlier from the

The east granitoid band.

Gollapudi Inlier.

[1] On the Geological Structure of the Eastern Coast from latitude 15° northward to Masulipatam, by R. Bruce Foote, F.G.S., &c. Memoirs, Geological Survey of India, Vol. XVI, 1880.

principal village lying near its centre. The northern inlier which lies 4 miles north of the Gollapudi inlier is in plan a very broad oval about 4 miles long by 3 in maximum width, but its boundaries are much hidden by jungle. It may be conveniently called the Chintakurti inlier from the village of Chintakurti (Chintakoor of map) which stands a good mile to west of the position given to it in sheet 75.

Chinta Kurti Inlier.

Except close to the Kondapalli range of hills, this band of granite gneiss has been planed down by erosive forces to a very level surface, relieved in but very few places by low hills and a few great piles of tors and rounded masses. Of the hills, the Juzzur (Trig. Station) hill and the Kondakedimay (Trig. Station) on the eastern side of the southern inlier, and a low but bold rocky ridge on the western side of the inlier, a little to the north-east of the village of Nangielaygondah, are all that need be noted.

Hills in the eastern granitoid band.

A large low ellipsoidal "whaleback" exposure of the granite gneiss occurs on the high ground north-east of Gollannapad (nearly in the centre of the southern inlier) and is, from its position and light colour, a very conspicuous object.

A rocky pile surmounted by an enormous tor forms a very striking object at the north-east extremity of the great tank east of Maddiré (Muddera).

The western granite gneiss band may be conveniently designated the Nandigama (Nundyganah)-Khammamett band from the two principal towns which stand upon it. It crosses the Munièru (Moonyair) valley near Pennagranchiprol, 10 miles north-by-west of Nandigama (but that part of its course was not examined). Its southern part is bounded by the overlying quartzite beds at the base of the Kadapa rocks of the Jaggayapetta (Batavole) basin, but further north it shows a considerable westerly extension; it was only examined along the east side of the Munièru valley. Its eastern boundary for a distance of more than 25 miles is formed by a narrow strip of Kadapa rocks which are faulted to the eastward against the median band of schistose gneiss before referred to.

The western or Nandigama Khammamett granitoid band.

The southern part of this band of granitoid gneiss forms a low rolling plain, the surface of which is almost everywhere marked by a thick layer of cotton soil, but in the central and northern parts the surface becomes much more broken and the extensive spreads of regur have been replaced by the gritty reddish loam derived directly from the decomposition of the rocks below. Protrusions of rock over the surface are seen on every hand, and much of the country can only be described as rugged. Besides the protrusions of the granite gneiss there are many long-stretched low ridges of barren rock formed by trap dykes which around the town of Khammamett form a perfect net-work that would offer no small obstacle to the construction of a railway. Northward of Khammamett the surface of the granite gneiss band becomes less rugged. To some extent this may only be apparent, for the country here is much less bare of wood than to the south.

Plexus of trap dykes at Khammamett.

Orography of the western band.

Although the surface of this granite gneiss band is much more broken and rugged in the northern Khammamett half than in the southern half or than in any part of the Juzzur band, very few of the eminences on it rise high enough to deserve the name of hills. In the southern part there is but one hill, the Cuddabode Trigonometrical Station, on the very edge of the Kadapa basin 9 miles north-west-by-west of Nandigama. The Cuddabode is about 200 feet high, and shows a very fine mass of great rocks around its summit.

A low hill consisting of great tor-like masses piled one over the other occurs at Mushti Kuntla (Mooshty Koontta) on the high road (as shown on the map) leading from Maddiré (Muddeera) to Khammamett. Another low hill of very typical rounded shape forms the Sitarampett Trigonometrical Station hill 4 miles to the north-west-by-west. Various low but very typical granite gneiss hills run along the western side of the Munièru valley, but these did not come within the range of my survey. The highest and most conspicuous hill in the granite gneiss band is that on which Khammamett fort has been built. I estimate it at about 300 feet high above the surrounding country over which it commands a very extensive panorama. A rather lower hill, showing some good tors on its summit, lies about a mile north of the fort.

A small rocky ridge consisting of a very uncommon variety of hornblende-micaceous rock is to be seen at the north-eastern corner of the great tank north of Jastipalli (Jausteepully) 14 miles north-east-by-north of Khammamett.

General petrology of the granitoid gneisses.

As far as my observation went, the predominant character of the granitoid rocks is hornblendic; micaceous varieties however do occur here and there, and in some cases both hornblende and mica occur together in the same mass. Epidote in the form of pistacite, is a frequent constituent of the granitoid rocks, *e.g.*, in the Juzzur Trigonometrical Station hill where it forms a very handsome rock of dark greenish-black colour relieved by light pinkish spots and streaks due to the quartz and felspar. A very handsome salmon-coloured and black variety is seen in some large tor-like masses which form a little inlier within the area of the Kistna alluvium about a mile east of the Kanchakacherla travellers' bangalow on the Bezwada-Hyderabad high road.

Much pistacitic granite gneiss occurs at Mushti Kuntla (Mooshty Koontta) 14 miles south-south-east of Khammamett, also in the bed of the Munièru at the ford on the road to Warangal. This is a beautiful pale-green and pink variety, which has in places been much polished by the river current, and shows its capability for furnishing a splendid ornamental stone.

The general colour of the rock in the western band is greyish and its texture mostly very coarse.

Included boulder-like masses of older hornblendic rock are common in places.

Very few quarries are to be found, and as the great rounded weather-beaten masses are frequently impracticable to an ordinary geological hammer, much less information as to the composition of the rocks could be collected *en passant* than in more civilised regions where quarries are numerous.

Noteworthy varieties of the granitoid rocks in the two inliers are massive hornblende rocks often of highly trappoid aspect, but not occurring as dykes, nor as far as could be seen as intrusive masses. These cover considerable areas in the two inliers; indeed, they seem to constitute the mass of the Chintakurti inlier. In the Gollapudi inlier they occur around Khauwapuram (on the Wyra) and westward nearly as far as Gollapudi.

The schistose gneiss band.

The median band of schistose rocks lies in its southern portion chiefly on the left (or eastern) bank of the Munièru. Northward of the junction of the Munièru with the Wyra the schistose band is confined to the tract between the two rivers. Its western boundary is here hidden by the alluvium of the Munièru to opposite Pennaganchiprol, where the granite gneiss of the western band comes in. Beyond this to the north the boundary between the schistose band and the western granitoid band is hidden by the superposition of a long narrow strip of Kadapa rocks which runs northward for more than 25 miles. To the northward of this outlier of Kadapa rocks the two bands of gneiss must be in apposition, but no section could be found showing their actual contact.

Orography of the schistose gneiss band.

No eminence deserving of the name of hill occurs on the surface of the schistose gneiss band in its southern part, and very few in the central part. In the latter, attention may be drawn to the rocky hill 7 miles north-by-east of Maddiré (Muddeera), which rises between 200 and 300 feet above the plain; to the low rocky hill a mile east of Pengol (edge of sheet 94) which will be described further on. Also to the low ridge on which stands the Pedda Gopatty Trigonometrical Station 9 miles south-east-by-east of Khammamett. The magnetic iron beds forming this ridge will be described further on.

The schistose gneiss area immediately south of the Singareni coal-field, which is a northerly continuation of the schistose band before described, contains numerous gneiss hills which may also be referred to, though they do not lie within the limits of the unsurveyed tract mapped by me. The principal hill in this quarter is the Gobugurti (Goboogoorty) Trigonometrical Station, which rises some 600 or 700 feet above the surrounding plains and forms a nucleus whence radiate some five or six lower jungle-covered ridges. To the east of the Gobugurti group of hills is the Ballapett (Bullapett) Trigonometrical Station hill and several other rocky or jungle-covered gneiss hills not shown in the map. South-west of the Gobugurti hill is a small detached hill marked in the map (sheet 75) as "H. Tree," while to the north-west of the extreme spur of the Gobugurti mass lies the Irlapudi Trigonometrical Station hill, a bold mass of hornblendic gneiss some 500 to 600 feet high.

The other hills to the west and north of Gobugurti hill belong to the transition or Kadapa rock system, and will be referred to when dealing with those rocks.

Petrology of the schistose band.

The more general variety of gneiss met with in this median band is a hornblendic variety which is frequently intercalated between bands of micaceous gneiss of varying character. Some of them are very highly micaceous and almost deserving to be ranked as mica schists. Richly felspathic forms are uncommon.

Massive beds are occasionally met with, which are of such coarse texture and so obscurely bedded as to approximate very closely to typical granite gneiss. As a rule, however, the most massive beds in the schistose bands are very distinctly bedded, no matter how coarse their texture may be.

The beds in the southern parts of the schistose band offer nothing of special interest, and exposures of the rock are not numerous, nor do they afford any good sections, the face of the country being mostly much obscured by great spreads of cotton soil. The most noteworthy outcrops met with were some fairly rich beds of magnetic iron which form a couple of low ridges, on the south-western of which stands the Pedda Gopatti Trigonometrical Station (9 miles south-east of Khammamett). Unlike the magnetic iron beds in Nellore and Salem and other parts of the south, the grains, flakes, and crystals of magnetite are imbedded in schistose hornblendic instead of in granular quartzose laminæ, with intervening hornblendic laminæ of very schistose character.

Magnetic iron beds of Pedda Gopatti.

The amount of magnetite included in the ferruginous laminæ is sufficiently great to form a fairly rich ore, but I did not notice any indications of the ore having been mined in those parts of the beds which I examined. The iron beds stretch away a considerable distance to the southward, and it is not improbable that they are connected with a bed of similar hornblendic magnetite schist which is exposed for a few square yards on a small red knoll lying about half way between Naugilaygondah and Prodatur-Agraharam (Agrarum). The northward extensions of the Pedda Gopatti iron beds are lost sight of a very little distance beyond the north end of the ridges.

If the infra-position of the granitoid gneiss to the schistose band be assumed to be true, there is no difficulty in understanding its relation to the tract of schistose gneiss already referred to, which lies between, and to the east of, the Maddiré (Muddeera) end of the Juzzur granitoid band and its northerly re-appearances, the Gollapudi and Chintakurti inliers. The schistose spread in that case is simply a survival (if the term be allowable with regard to inanimate objects like rocks) of part of the overlying schistose series which has there escaped complete erosion, probably because it lies in a hollow. If the hypothesis of the infra-position of the granitoid series should be disproved by subsequent observations, then the relative positions of the two series of rocks can only be explained by supposing the metamorphic forces to have acted with far greater intensity in certain tracts than in other adjoining ones. This variation in intensity of the metamorphic forces may have been largely assisted by the original differences in texture and mineral composition of the original sedimentary deposits acted upon. It is quite conceivable, indeed very probable, that coarse thick-bedded gritty sediments would assume a much more massive structure under the influences of metamorphic agencies than fine-grained sandstones or shales which would retain a schistose appearance. The presence of small patches of granitoid gneiss within the general area of the schistose variety may very likely be safely explained by assuming them to have been local deposits of very coarse

Relations of the schistose gneiss extension to the eastern granitoid band.

Noteworthy varieties of the granitoid rocks in the two inliers are massive hornblende rocks often of highly trappoid aspect, but not occurring as dykes, nor as far as could be seen as intrusive masses. These cover considerable areas in the two inliers; indeed, they seem to constitute the mass of the Chintakurti inlier. In the Gollapudi inlier they occur around Khauwapuram (on the Wyra) and westward nearly as far as Gollapudi.

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Relations of the schistose gneiss extension to the eastern granitoid band.

texture, which were exceptionally affected by the metamorphic changes undergone by the whole mass of rocks.

Rocks of the eastern extension.

The rocks which occur in the eastern extension of the schistose band are chiefly hornblendic and micaceous gneisses, varying from nearly massive to highly schistose varieties. None of any special interest were noted.

The only schistose rocks which deserve separate notice are a few beds of magnetic iron' of very small size (from 6 inches to 1½ feet thick) which occur on the eastern boundary of the area under consideration, between the villages of Pengol and Utur, both situated in an outlying portion of the Nandigama Taluq (Kistna district). They are but little exposed, though a good deal of debris derived from them is scattered over the surface.

Two or three small beds of similar character and size occur about 5 miles to the north. The ore is in all cases of fair quality, but the quantity is too small to give the beds any importance. They did not appear to have been ever worked.

Granular quartz rocks.

To the schistose series I reckon from their position some beds of granular quartz rock of precisely the same character as those forming the many remarkable bare ridges round the towns of Madura and Tinnevelly. These beds form a low broad rise beginning immediately north of the large village of Pengol (see page 16) and extending for 2 or 3 miles north-north-east. The granular quartz rock is frequently exposed, but only in low flat sheets in which the bedding is badly seen, while the extensive scrub jungle covering much of the rise helps to make the lie of the beds still more obscure.

Pengol hill beds.

A more instructive display of very similar granular quartz rock occurs a little to the south-east just within the limits of the country shown in sheet 94. Here a low rocky ridge rises out of a plain covered with red soil, and shows the bassett edge of a great bed running south-south-west to north-north-east; with a dip of 40° to 45° east. The quartz is (where freshly broken) of pale pinkish-white to pale reddish-brown colour and nearly diaphanous. It includes many minute and a few large brilliant spangles of reddish-grey specular iron. Where weathered the surface of the quartz rock is often covered in small patches with reddish-brown lateritic films. A direct connection between these granular quartz beds and those to the north-eastward of Pengol doubtless exists, but want of time did not allow of my tracing it out.

Further north the eastern spread of the schistose band is to a very great extent marked by great spreads of cotton soil,? and the few outcrops, chiefly of hornblendic gneiss that are met with, are of no special interest.

Rocks north of Khammamett-Kullur road.

After crossing the road leading from Khammamett to Kullur the country begins to get hilly and broken and the spreads of cotton soil disappear, but the rocks are here much hidden by jungle. The mass of hills forming and surrounding the Gobugurti Trigonometrical Station consists of great beds of hornblendic and micaceous gneiss in frequent alternation. To the north-west of the Irlapudy Trigonometrical Station hill a large

Crystalline limestone.

bed of grey crystalline limestone intercalated among beds of hornblendic gneiss which have a local strike from west-by-south to east-by-north with a high southerly dip. The limestone cannot be much less than 50 feet thick. Further north still, and about half a mile east of Kamapalli, is a medium-sized bed of magnetic iron of rather poor quality running north-north-east and dipping 60° east.

The Singareni iron bed.

No connection was traced, though it may very likely exist under the surface soil between this bed and a very large and important bed of magnetic iron which commences about 2½ miles to the north and continues thence for fully 3 miles till it runs under the overlying mass of the Kadapa rocks at a point only about half a mile west of the edge of the southern boundary of the Singareni coal-field. As this bed of magnetic iron is traced northward from its southern extremity, it increases in thickness by the appearance of other beds above and below it till at last it forms the mass of a considerable hill some 150 feet high just under the parallel of 17° 30′ North. The iron-beds may be traced along the valley north of this hill for about half a mile when they rise again and form a considerable ridge 250 to 300 feet in height by estimate. The ore in these beds is very rich in quality and really appears to have been placed here by nature, in order that an iron industry might arise as soon as the coal measures close by are made to yield up their carbonaceous treasures. As the line of rail coming from Bezwada could with the greatest ease be carried close along the foot of these ridges, every facility exists for bringing the ore and fuel together at some handy spot, while the great limestone beds of Kadapa age, which occur at no great distance to the east and west of the coal-field would furnish an inexhaustible supply of flux for the smelting works.

Intrusive rocks.

The only intrusive rock occurring in any notable quantity is dioritic trap, dykes of which are numerous in some parts, as the middle part of the Munièru valley. All as far as my observation went are dioritic and mostly of medium coarseness of texture. Many are of considerable size, 50 to 60 feet or more in thickness, and from their superior hardness stand out well over the surrounding granite gneiss. Their surfaces have weathered into a very "blocky" condition, and fallen masses almost everywhere mask their contact with the granite-gneiss. Some of the ridges rise as much as 50 or 60 feet above the surrounding country. The most southerly of all the trap intrusions noted is the most important and of such size that it cannot be classed as a dyke proper. It lies about 5 miles north-west of the junction of the Kistna and Munièru, and immediately south of the village of Thoralapadu (Thoralapandoo). The intrusive rock is a diorite differing in no way from that in the true dykes of the neighbourhood. The trap mass extends for rather more than 3 miles southward, and is not less than a mile across near the middle. Unfortunately it is overlapped all round by a very thick and continuous sheet of regur which completely hides its boundary, and no contact with the gneiss around it was traceable.

All the trap intrusions noticed are, judging by their petrological aspect, to be

reckoned as belonging to the great series which was injected into the gneissic rocks prior to the deposition of the Kadapa or Transition rock system.

Granite veins are very rare and small both in size and length. The same may be said of true quartz veins, none of noteworthy size were met with.

Of brecciated quartz reefs such as play such a prominent part in the Cuddapah and Anantapur districts, and elsewhere, only one example was seen. This is a rocky ridge, about ⅓rd of a mile in length, about 2¼ miles west-north-west of Juzzur. It has a course from south-east-by-south to north-west-by-north. The peculiar brecciated or quasi-brecciated character of the reef is well seen on the pale greenish-white rocks which form the crest of the ridge in its northern part.

II.—The Kadapa or Transition Rocks.

Frequent reference has been made in the foregoing pages to the several outliers of the Transition rocks which occur in the Munièru valley and which by their position prove that the two great basins of rocks of that age which exist in the lower valleys of the Godavari and Kistna respectively were once united. Four of these outliers were mapped, and another is known to exist in the very jungly country south-west of the Junjurlagutt Trigonometrical Station hill. This latter outlier could not be mapped, as owing to the rough and jungly character of the country it would have required several days' work, which could not be spared because of the pressure of more important work. Starting from the south the outliers are:—

1. Ragavapur (Raugavapoor), Trig. Station Hill.
2. Pallagiri Hill.
3. Jennel Gudda Hill.
4. Shernavála ridge.
5. Mucherla (Moocherla) Trig. Station Hill (unmapped.)

Ragavapur hill outlier.

1. The Ragavapur Trigonometrical Station Hill is a bare steep Hill which rises some 500 feet above the valley of the Munièru and 574 feet above sea-level. It consists of two or three great beds of quartzite varying in texture from coarse grit to a fine jaspideous quartzite, which is very slightly hæmatitic, and here and there of reddish colour. The quartzite beds are separated by micaceous or argillo-micaceous schists of silvery-grey, greenish-grey, and red colours, the latter being of various shades. The beds have been considerably contorted. At the south end the quartzites show a low easterly dip; at the little gorge in the ravine which scores the east side of the hill, they are slightly inverted or vertical; while at the Trigonometrical cairn near the north end they begin to curve round westward in a strongly marked curve which looks as if its continuation would join the beds in the Pallagiri hill. No continuation is however visible in the valley between the two hills which is filled with the sandy alluvium of the Munièru. The dip of the quartzite beds close to the Trigonometrical cairn, and just where the westward curve commences, is from 40° to 45° east. It is quite clear from the position of these beds with reference to the gneiss, which appears very near to the eastern foot of the hill, that the Kadapa

rocks are the remains of a long anticlinal fold faulted down against the gneiss on the east.

2. *The Pallagiri Outlier.*

Pallagiri hill.

The structure of Pallagiri hill is very similar to that of the Ragavapur hill, and it is very probable that it is formed of the same series of beds, for in mineral character the Pallagiri beds agree closely with the Ragavapur beds, especially in the character of the quartzites, which vary locally from distinct coarse grit to very fine close-grained jaspidean schists. The dip of the beds is about 55° east, and there can be no doubt that here also the boundary is faulted down against the gneiss.

The gritty character of the original sandstone is very clearly revealed in parts by the action of weather, and may be made out even in unweathered parts by careful macroscopic inspection. The true water-worn rounded surfaces of the individual grains are quite clear.

3. *The Jennel Gudda Outlier.*

Jennel Gudda hill.

Jennel Gudda, 6 miles north of Ragavapur hill, is a round-topped steep-sided hill which throws out a couple of diverging spurs to the east and north-east. In plan the mass of the hill represents a strangely compressed horse-shoe, the sides of which form ridges which slope down slowly in the first half of their course and then steeply till they end in small bluffs which seem to indicate the position of the line of fault by which these Kadapa beds are thrown down against the gneiss. The actual boundary is not seen owing to thick soil. The ridges are formed by rather thick beds of quartzite separated into two series by micaceous and argillaceous schists. The uppermost beds on the hill stratigraphically are a very ferruginous argillite schist which lies in the valley between the two quartzite ridges. This is so bright a red in colour in parts that it is dug out to be used as reddle.

The northern extremity of the outlier is hidden under thick cotton soil, but may be traced for some distance northward as a low and steadily decreasing ridge forming the watershed locally between the Munièru and the Wyra.

4. *The Shernavála Outlier.*

Shernavála ridge.

The Shernavála outlier is the long narrow strip of Kadapa rocks which runs for a distance of 25 miles nearly parallel with the course of the Munièru at a distance of from 3 to 6 miles. For the greater part of the distance it forms the watershed between the Munièru and the Wyra. I have called it the Shernavála outlier because it was close to the village of that name that I first came upon it, and that the very remarkable quartzite breccia which there occurs at the base of the limestones enabled me at once to recognise the rocks as belonging to the Kadapa system. The southern end of the outlier lies 8 miles north-north-west of Jennel Gudda hill, and is formed by two small rocky hills showing strong outcrops of quartzite. The beds trend north-west for about a mile, and north-west-by-north for another mile, they then run north up to the Shernavála Trigonometrical Station. This southern part of the

ridge is very low and much obscured by cotton soil and low but thick jungle, so that the eastern boundary is very difficult to make out. Near to Shernavála the ridge rises again and stands from 40 to 60 feet above the granite gneiss tract to the west, but to the east it slopes down almost imperceptibly to the schistose gneiss band.

Shernavála Trig. Station.

The rocks seen at the Shernavála Trigonometrical Station are highly cherty blue limestones which are underlaid by a remarkably fine-grained jaspideous quartzite breccia of rich reddish, yellowish, and brown tints. The breccia seems to be merely local deposit, and is wanting in many sections both north and south of Shernavála station. Underlying the breccia is a micaceous schist which might belong either to the Kadapa series or the gneiss, but I could not satisfy myself which series to assign it to.

Letchmapur hill.

North of the Shernavála ridge the outcrop sinks down a good deal but rises again a couple of miles further on in the Letchmapur Trigonometrical Station hill. The limestone beds which seem to be continuous all along the west side of the band shows in great force around the Letchmapur hill. The limestone is grey in colour, cherty, and greatly contorted and vandyked. The dark variety of limestone occurring here shows a decided blue colour when freshly broken. Overlying the limestone are beds of micaceous argillite with here and there small beds of limestone. Small lenticular inclusions of the same rock are numerous. The limestones are generally sub-crystalline, but sometimes really crystalline. The argillite beds which are of dark-greenish or bluish-green grey colour roll about a good deal, but have a general dip to the east. The eastern boundary is not seen at Letchmapur, owing to a great accumulation of kankur mixed with debris of the jaspideous breccia and limestone.

North of Letchmapur the surface of this strip of Kadapa rocks is much obscured by cotton soil.

At Narrainaypolliam (site of an abandoned village) the transition beds show very slightly, being traceable only by slight outcrops of quartzite.

Kodamur section.

At Kodamur highly cherty limestone with some ferruginous brecciated cherty quartzite forms a narrow rocky ridge 50 or 60 feet high above the surrounding country. To the north of the village the ridge rises considerably and joins the group of low hills which lie eastward of Khammamett, and here the outlier attains its greatest width of about

Section east of Khammamett.

2 miles. The hills consist of rather shaly quartzites with numerous beds of limestone in the valleys between. The rocks in the western side of the band show some extensive contortions, but on the eastern side they have the normal easterly dip towards the faulted boundary. Considerable contortion of the quartzite beds is also visible still further to the north near Ragunadhapuram. North of Ragunadhapuram the base of the Kadapa rocks is again formed of

Ragunadhapuram limestones.

limestones, but in this case they are very little altered and almost lithographic in their very fine and close texture. They are fairly thick-bedded and mostly of grey colour. They appear to be over-

laid by quartzites, but time did not allow me to explore the thickly wooded hills lying between the limestone beds and the Chintakurti Trigonometrical Station.

5. *The Mucherla Outlier.*

This outlier consists of quartzites forming the crest and south face of the ridge which runs north-eastward from the Mucherla (Moocherla) Trigonometrical Station. The beds are cut off abruptly at their western extremity, and there is certainly no connection between them and the quartzites on the Chintakurti hill 5½ miles to the south-west-by-south, the whole intervening space being occupied by gneissic rocks. The quartzites appear to extend further eastward across the valley drained by the headwaters of the Wyra and to join the hills north and north-east of Mudlapad which contain numerous bands of quartzite. A bed of sub-crystalline limestone is exposed to the west of the small tank north-west of Mudlapad, and traces of ferruginous quartzite breccia are very numerous in the talus along the south foot of the hills. The hills are thickly covered in most parts with low tree jungle, and it is only when quite close to them that their petrological distinction from the neighbouring gneiss hills becomes apparent. This is especially the case at their eastern extremity.

The plain immediately south of these hills consists of gneiss with various beds of massive hornblende rock against which the quartzites are unquestionably faulted down. As before mentioned, want of time prevented my working out the details of this interesting outlier of the Kadapa rocks. It is I believe separated from the main spread of the Godavari basin of the Kadapa rocks by a considerable fault running nearly north and south, a little to the west of Junjurlagutt Station hill.

III. *The River Alluvia.*

But little can be said of the river alluvia, that of the Kistna excepted, no features of special interest having been worked in connection with them.

Alluvium of the Munieru.

The alluvium of the Munièru is generally very sandy, as might be expected from a river draining so large an area occupied by highly siliceous rocks. Near its mouth, however, the banks and small islands in it consist mainly of dark silts formed of washed up cotton soil.

Of the Wyra.

The Wyra, which through the greater part of its course drains a regur covered country, shows much dark silt in its banks, but here and there, as for instance just below its junction with the Gumplagudem stream, there are considerable shows of sandy alluvium. The valleys of the headwaters of the Wyra contain considerable deposits of loam, often with much kankar, resting upon or intercalated with beds of coarse shingle.

Gravels.

Much attention was paid to the gravels in the dry beds of all the rivers and streams in order to ascertain whether any debris of the carboniferous rocks might be contained in them which might help one to trace out the localities where outliers of the Gondwana rocks might occur, but no outliers were discovered by this mode of search. It was very remarkable how very few pebbles of the various Gondwana sandstones and of the

softer members of the Kadapa rocks were to be found in the streams after the first few hundred yards below their original sites. All the softer masses of stone seem to have been speedily reduced to sand by the violent action of the streams, which only flow sufficiently to move the debris in their beds when swollen by heavy rains, but then become furious torrents. No organic remains were noted in any of the alluvia.

The diamond gravels of the Kistna.

The most important alluvial deposits within the area now under consideration are those lying on the left bank of the Kistna along what may be conveniently defined as the Amaravati (Umarawutty) reach of the river. These deposits consist of sandy shingle beds which have in many places been worked for diamonds. No workings were in progress at the time of my visit, though large areas of the shingle beds have not been turned over as yet. From enquiries I made from the people at Mugalur and Partial (Purtyall), I believe that the diamond industry is crushed by the heavy royalty levied and by other absurd restrictions imposed by certain people at court in Hyderabad. There is certainly no geological reason why the undisturbed gravels should not be as rich in diamonds as the positions of the same beds explored in past times. That the old workings were held to be of considerable value is evident from the fact of their having been retained by the Nizam when the Guntur circars were made over to the East India Company.

The shingle consists mainly of quartzite which has been very highly water worn. The number of gneissic pebbles occurring in the shingle is very small, while agates and trap pebbles derived from the Deccan Trap are of great rarity in the sections examined.

The gravels lie at considerable levels above the river, but it is almost impossible to trace their upper boundaries because covered by great cotton soil spreads.

IV. Sub-Aërial Formation and Soils.

The sub-aerial formations met with were very few and mostly of small extent and interest. Ferruginous pisolitic gravel is scattered in small quantity over the surface of the red soils where they are richly ferruginous and in the proximity of magnetic iron beds and of the hæmatitic granular quartz rocks, *e.g.*, of Pengol hill (see page 18). The dark-brown to bluish-black often botryoidal incrustations of the outer surface of parts of the jaspideous breccia in the Kadapa rocks, especially on the knoll south of Shernavâla Trigonometrical Station, and at Kodamur ($5\frac{1}{2}$ miles south-east of Khammamett) are due to weather action on small reniform masses of dense limonite (brown hæmatite) enclosed in the rock. The same action, but on a much larger scale, has taken place in some of the brecciated quartzites in the Mucherla outlier and in a breccia bed close to the boundary of the Kadapa rocks where crossed by the road leading from Singareni town to the centre of the coal-field near Yellindellapad, the cementing medium in these cases is red hæmatite, rich enough to have been used as an ore by the native smelters.

Hæmatitic incrustation in breccias.

Kankar deposits.

Small deposits of carbonate of lime in the shape of vermicular or nodular kankar are common enough, as they are in all tracts where hornblendic rocks are abundant. Only one locality was

noted where the kankar deposit was sufficiently extensive to attract attention. This was to the west of Rajawarrum ($4\frac{1}{2}$ miles north-east of Maddiré).

Only two classes of soil are represented in this region—the red and the black.

Soils.

Of these the black occupy nearly all the southern and eastern central parts of the country south of Khammamett and the hills to the east of it, these parts being open and approximately level. Wherever hills rise in the plain, or the surface is rugged and broken, red soil puts in an appearance. This is markedly the case along the western side of our area, where the granitoid rocks have a rough and broken surface. Very few patches of cotton soil occur here.

No spreads of soda or white soil were observed.

Geological Sketch *of the country between the* Singareni Coal-field *and* Hyderabad, *by* R. BRUCE FOOTE, F.G.S., *Deputy Superintendent, Geological Survey of India.* (With a map.)

The geological data here given were gathered while carrying a broad traverse from the Singareni Coal-field westward to Hyderabad, in order to ascertain whether any outliers of the Barakar or Indian carboniferous rocks occurred in that tract, the presence of which might influence the choice of direction for the new railway to be constructed between Hyderabad and Warangal.

Existence of coal-measures disproved.

The examination of the tract in question unfortunately dispelled the hope of finding any outliers of the coal-measure rocks westward of the Singareni coal-field.

The whole large tract included in this traverse was found to consist of bands of granitoid gneiss of slightly varying characters overlaid only by the local alluvia of the various small rivers traversing the country or by unimportant subaerial deposits of very recent character. Of intrusive rocks a considerable number of trap dykes were mapped, but many were not followed up through the extensive scrub jungles for want of time.

Physiography of the tract examined.

The country is, as a rule, open and undulating, but rocky hills both isolated and in small groups are not unfrequent, and some of them rise boldly out of the plain to a height of from 500 to 800 feet. Smaller hills are numerous, as are also great rocks and tors as well as low broad "whaleback" eminences, which afford a good look-out over the surrounding country. But for these frequent eminences a far greater time would have been requisite to enable one to acquire anything like a good idea of the country, as over great tracts the scrub jungle is just high and thick enough to shut out the view even when traversed on horseback. The jungle is not thick enough, however, to hide the character of the country when overlooked from an elevation of a few score feet or so, and the numerous rock exposures show up well, even when flat, or nearly so, because of their light colour and generally more or less glistening surface. The latter quality often makes them conspicuous at a distance of several miles.

Shape of area covered by traverse.

The shape of the area covered by the traverse may be described roughly as a scalene triangle whose shortest side corresponds with the course of the Munièru river for 6 miles northward from Khammamett and then for nearly 40 miles with the course of the Garlah, its principal northern tributary, the longer sides stretching away to Hyderabad with distances of 96 and 105 miles respectively.

The country east of the Garlah had been examined by Dr. King, who had also made a traverse from Khammamett to Warangal *viâ* Biravol (Beeroal), Murrypuddah, Nelli Kudru (Nelly Koondroo), and Kothoor, thus extending the known tract for a considerable distance northward of the triangular area of my traverse.

Hydrology.

All the drainage of the triangular area falls into the Kistna by the Munièru, the Paléru (Pallair), and Mussi (Moosy) and their respective tributaries. The Mussi is the only one of these rivers which has a pretty constant flow, but even it in the hot and dry months often shows a perfectly dry bed for reaches of several miles in length. This is doubtless due in very great measure to the absence of anything like real forest. Even in the most jungly tracts along and east of the upper courses of the Munièru the thin jungle, which as Hyderabad is approached dwindles to mere stunted scrub or disappears altogether, is utterly inadequate to shelter the surface against the vertical rays of the sun in the hot season. In its present condition most of it may be described as an arid country cursed by large flocks of goats. In no other part of South India have I seen so strong a tendency to consume all the cattle manure as fuel,—a fact which attracted the notice of more than one of my Madrassee servants.

Orography.

It has been already pointed out that many hills, some in groups and some quite isolated, rise from the surface of the granite gneiss tract here dealt with. The principal of these may be enumerated, as they afford fixed points for reference in a country where many of the villages do not now hold the same importance that they did when Atlas sheet No. 75 was originally constructed. They may be advantageously considered in groups, as far as possible, some of them hardly belonging to any one group because lying too far apart from any others.

Kandi Konda group.

The most important of these groups in the eastern part of the area under consideration may be called the Kandi Konda group from the hill of that name which lies a little south-east of the intersection of the meridian of 80° East by the parallel of 17° 30′ North latitude. To the north-west-by-north of Kandi Konda lies a considerable number of detached rocky hills rising out of the extensive but thin and low forest which here covers the whole face of the country. These hills all show, more or less, the typical rounded outlines of granitoid masses or equally typical bold rocky masses crowned in many places by great tors. In the northern part of the group Bali Konda and the two hills immediately north and south of it are the most lofty and striking.

Kandi Konda itself is a fine hill, rising 800—900 feet or more above the plain. It is crowned by a small temple (the "Pagoda Station" of sheet 75), and was formerly fortified, as shown by three or four ruined gateways one has to traverse in

ascending and by a series of cisterns, partly natural, partly artificial, a little below the summit. These contained a good supply of water even in April. The hill was evidently of some importance formerly, as it has given its name to the taluq[1] in which it stands. From the summit of the hill the beds of granite gneiss composing it are seen to trend southward to the lower hills near Hydershaipetta on the Munièru. In the western part of the group the principal hills are the Narasimhapetta Pagoda hill, west of Kuppelvoy, and the Butchurazpully hill which lies 5 miles south-south-west of Kandi Konda. The continuation of the group south of the Munièru shows two very bold and picturesque hills the Goniguth (Trigonometrical Station) and the Jallipalli (Jullypully) Drug hill, each of them showing an approximately conical mass towering 600—700 feet above the plain around. The other hills which lie round Murrypuddah and Pindipol are much lower.

Urlagondah hill.

South of the Kandi Konda group, but hardly to be reckoned to it, is Jettygonta Trigonometrical Station, a rather remarkable pile of huge tors. Nine miles west-south-west of this hill is the Urlagondah Trigonometrcial Station, a fine bold hill rising some 500 feet or more out of the plain over which it commands a very extensive panorama remarkable for the great number of low flattish exposures of rock which show through the red soil here prevailing. The light colour of the rocks and their shining surfaces produce an effect unlike anything I have seen elsewhere in granite gneiss districts.

Arwapalli group.

About 20 miles west-by-north of Urlagondah lies a small group of bold rocky hills which I will call the Arwapalli (Arwapully) group from the Arwapalli hill, a station of the Trigonometrical Surveyors which is the most important and highest mass in the group. It is a fine bold mass nearly conical in form, rising fully 800 feet above the plain, and is the most conspicuous hill in that part of the country. Kundaguth hill (Station), the easternmost member of this group, is also a considerable hill and nearly as high as Arwapalli. This group includes a number of smaller hills and masses not shown on the map. They have all been denuded of the jungle which formerly clothed their flanks.

Vizianagram group.

Twenty miles or a little more north of the Arwapalli group lie the southern members of another small group which I will call the Vizianagram group after a small but interesting hill bearing that name. The beds of granite gneiss composing the hill have a north-westerly strike and can be very distinctly traced across the intervening plain into the Zaffarghur hills, a distance of 4 or 5 miles. The south-western part of the group is formed by the Kolonpalli hills, all typical specimens of granite gneiss hills.

Madapur group.

The next group of hills may be termed the Madapur group from the village lying nearest its centre. The group includes six considerable hills rather widely detached and a number of smaller ones, several of which are not shown in sheet 75. This group lies 12 miles south-west of Vizianagram hill. The principal hills in the group are the Kul Konda (Koolconda) at the northern extremity, the Madapur Trigonometrical Station hill,

[1] The Kasba of the taluq is not at Kandi Konda village, but at Nelli Kudru (Nelly Koondroo), 20 miles north-west-by-west.

two large hills north-east of Madapur, another large one to the west of the village, and lastly a very fine bold hill 700—800 feet high 6 miles to the south-east.

To the west of the Madapur group the country for a distance of over 20 miles, though rising steadily westward, shows many fewer hills, and those are with one exception of much smaller size. They are too scattered to be included in groups, and do not require special notice.

Sudi Konda.

The only one of importance is a lofty conical mass which rises on the north side of the Mussi river at a distance of 3 miles from the large village of Vemal Konda (Vamul Conda). The local name of this hill is Sudi Konda. It is the most perfectly conical granite-gneiss hill of large size that I am acquainted with, excepting possibly the Suttu Pottai in South Tinnevelly. Sudi Konda, which is fully 600 feet high above the plain if not considerably more, owes its shape chiefly to the concentric peeling off on a gigantic scale of thick layers of rock.

The numerous granite-gneiss hills south of the Mussi river did not come within the limits of my traverse.

Bhonagir hills.

Ten miles west-north-west of Sudi Konda commences a set of granite-gneiss hills that joins on to the Bhonagir group which culminates in the very fine hill on which Bhonagir Drug is built. This is one of the finest examples of a fortified granite-gneiss hill in South India and must in olden times have been a place of immense strength.

Of hills untouched by the hand of man the Raghir hill, 3 miles to the north-east, is a very beautiful example. The rocks here rise in bold peaked masses, amongst which a few fine trees are still growing, the whole being the most picturesque spot in the country between Hyderabad and Bezwada.

Parvatgiri hills.

The group of hills to the north of the road from Bhonagir to Hyderabad though picturesque is much lower than the Bhonagir hills. The low hills close to the road are of no special interest.

Crystalline rocks not closely examined.

The character of the work involved in making a search for coal-bearing rocks over a vast area of country in a very limited space of time debarred all close study of the older rocks. Such observations as were made in passing were necessarily rather rough. Quarries are in many parts but few and far between, and the greatly weathered surfaces of the undisturbed rocks do not afford sufficient information to admit of close determination of the exact character of the rock. The detailed description of the petrology of this region will have to be given after a much closer examination of the crystalline rocks than it was in my power to make. I can only roughly indicate the great features which could not escape notice.

Difficulty of distinguishing weathered rocks.

The granite-gneisses occur, as already pointed out, in great bands running in a north-north-westerly direction across the line of traverse. Of these great bands the most easterly belongs to the Nandigama-Khammamett band of coarse grey, generally hornblendic granite-gneiss. This includes the tract of country occupied by the Kandi Konda group of hills above described. Micaceous and epidotic (pistacitic) varieties occur occasionally, but are not common. It is not improbable, however,

that the micaceous varieties are much more common than appears on cursory inspection, for the mica crystals are more affected by weathering than the quartz, felspar, and hornblende. The hornblende also is often unrecognizable on the weathered surfaces; it is therefore very easy to pass from a bed of hornblendic rock on to a really micaceous bed without being immediately aware of the change. As a matter of fact, it was generally unsafe to assume the special character without getting sight of a freshly broken unweathered surface, which was frequently impossible as the great rounded masses were too deeply weathered to reveal their internal structure to the questioning of an ordinary geological hammer.

Westward of the coarse hornblendic band comes a less coarse variety in which micaceous beds are rather more frequent, or at least more apparent. To this band belong the Vizianagram, Arwapalli, and Madupur groups of hills.

West of this, again, comes a band of coarser and more porphyritic granite gneiss of coarse texture. As seen in the quarries to the south-west of Mutkur (Mootkoor), it is a greyish pink rock, which when closely examined consists of pinkish orthoclase, black mica, and white quartz.

The bedding is only seen when large spreads of the rock are exposed.

Further west hornblendic varieties again appear to predominate and the granitoid character of the rock becomes more marked, the original bedded structure of the rocks having been entirely, or almost entirely, obliterated by excessive metamorphism.

Special varieties of the granite-gneiss.

Specially beautiful examples of granite-gneiss were met with at several places, *e.g.*, at Autapuram (Owtapoorum) near the southern end of the Vizianagram group of hills, where a lovely pale pink and green variety of rock occurs, the felspar being pale pink (flesh colour) in a matrix of pale green pistacite with a few spangles of graphite. About 13 miles south of this beautiful epidotic rock is a very fine black variety of close-grained hornblendic granite-gneiss forming the rocky hill on which stands the Punnagherry Trigonometrical Station.

One of the handsomest rocks to be seen in the country is a deep red and green epidote gneiss, which is exposed in the bed of a stream between Gutkassara and Auvunumpett, 12 miles east of Secunderabad.

Trap-dykes.

It would be a mistake to omit noticing the trap-dykes occurring in the granite-gneiss area, for they occupy important positions in many parts, and in not a few cases attain to very large size. For the most part they consist of moderately coarse diorite of black or greenish-black colour, rarely of a distinctly green tint; the few of the most important may be enumerated :—

1.—A group of large dykes, north of Maddallapatti and 3 miles west of Khammamett.

2.—A very large dyke at Pindipol (Pindypoal) at the south end of the Kandi-Konda hill group.

3.—Two large dykes south of Kandi Konda.

4.—A very large dyke at Inkirti, 20 miles north-west of Kandi Konda.

5.—A very large dyke running for more than 12 miles north and south through the centre of the Madapur hill group and forming several considerable ridges.

6.—A large and lofty dyke north and south at Gurjalla on the south bank of the Mussi river, possibly an extension of No. 5.

7.—A pair of great dykes which form the crest of the southern part of the great Sudi Konda hill rising some 400—500 feet above the plain.

8.—A large dyke forming the crests of the Kanchanpalli (Kunchunpully) ridge, 8 miles north-west of the Sudi Konda dyke.

9.—A very large dyke running for 14 miles north-east-by-east, south-west-by-west, passing close north of Bhonagir Drug hill and forming several very conspicuous hill ridges along its course.

10.—A large dyke crossing the plain east of Gutkassara in a nearly north and south direction. It forms several considerable bare rocky ridges and is lost to sight at the northern end in the Parvatgiri (Purvatgerry) hills, while to the south it disappears across the crest of Bachawaram hill on the right bank of the Mussi.

Porphyritic trap.

In a few dykes the diorite is markedly porphyritic, and encloses large crystals of green felspar in a green matrix. Examples of this are to be seen at Nagawaram, 2 miles south-west of the great Inkirti dyke (No. 4) above mentioned, and at Surruwaillu, 5 miles south-east of Kandi-Konda.

Granite and Quartz veins.

No granite or quartz veins of any size were seen in the course of the traverse, but a great plexus of small and often anastomosing veins of common coarse pinkish-grey granite was observed cutting up the compact grey granite-gneiss in a very remarkable way in a hill 4 miles north-east of Autapuram (Owtapoorum). The granite veins are so numerous that they form very nearly half the mass. They strongly suggest the idea that they have originated not by intrusion but by excessive metamorphism along the lines of jointing and other fissures in the original rock.

Brecciated quartz rock.

Three good-sized and conspicuous runs or reefs of brecciated quartz rock form the mass of a moderately high ridge which runs north-eastward from the left bank of the Alléru (Allair) river, 3 miles above its junction with the Bikalèru (Beekullair).

Sub-aërial formations and soils.

With the exception of a few unimportant deposits of kankar no sub-aerial formations were noted.

Soils.

The soils are almost invariably varieties of *lal*, or red, soil, and mostly very poor and gritty. Here and there rich soils have been formed by the decomposition of the trap-dykes or of extra hornblendic varieties of the granite-gneiss.

Cotton soil is of very rare occurrence and only a few small spreads of it were noted a few miles eastward of Bhonagir.

Note on Coal *and* Limestone *in the* Doigrung River, *near* Golaghat, Assam, *by* TOM. D. LA TOUCHE, B.A., *Geological Survey of India.*

It has long been known that in the Námbar, a tributary of the Dhansiri crossed by the Nága Hills road 12 miles to the south of Golaghát, there are exposures of coal and limestone,[1] and some time ago I was informed by Mr. Clift, Executive Engineer, Assam Railway Surveys, that a native surveyor of his party had found coal and limestone in the Doigrung, a stream flowing parallel to the Námbar and 3 or 4 miles to the west of it. As his description seemed to indicate that there was a considerable quantity of the minerals there, I spent a few days on my way to Upper Assam this season in visiting the locality.

The coal is exposed in the Doigrung about 7 miles above the point where the forest path from the Dimapúr road to Murphulani crosses the river (see Topographical Survey Sheet No. 35, 1 inch = 2 miles), and where a forest bungalow has been recently built. The spot may be reached by following the path southwards from Murphulani, and turning south-east at the village of Burabassa (not marked in the map, but close to the site of the deserted village Leti). The coal is seen twice in the bed of the stream, being probably repeated by a fault, with an interval of about ¼ mile between the exposures, and in each case is overlaid by calcareous shales containing large nodular masses of limestone, crowded with fragments of shells. The seam is in each case about 3 feet thick, the greater portion of it being under water and extending nearly across the river with a low dip to west-north-west. The coal contains numerous nests and specks of the fossil resin characteristic of the cretaceous coal of the Khasia and Garo Hills, and is presumably of the same age. Gneiss occurs about ¼ mile further up stream, and the high ridge to the west of the Doigrung is apparently all of the same rock. It is difficult to form an opinion as to the extent of the coal, but this is probably a portion of the same bed as that found in the Námbar. Even if it were continuous between these streams, the greater portion of it would be below the water level of the valley, and seeing that far larger deposits are easily available in Upper Assam, I do not consider this coal to be of practical importance at present. In the event, however, of the Assam Railway being brought down the Dhansiri valley, this coal may turn out to be of some use, if the quality should improve to the deep; the sample taken at the outcrop gives the following very poor result on assay :—

Moisture	5·08
Volatile matter	31·06
Fixed carbon	15·10
Ash	48·76
	100·00

The occurrence of limestone in this locality is a fact of far greater importance, there being so great a scarcity of this rock in the Naga Hills, the lime for which is at present obtained at a great expense (about Rs. 10 per maund) from Sylhet. Mr. Medlicott in 186[illegible] expressed his surprise that no use had been made of the

[1] Medlicott, Memoirs, Geological Survey of India, Vol. IV, Pt. 3, p. 26. Mallet, *Ibid.*, Vol. XII, Pt. 2, p. 17, note.

limestone on the Námbar, but from that day to this only one attempt, and that a feeble one, has been made to burn the stone.

The Doigrung limestone is found about 3 miles above the forest bungalow above mentioned, where a bed, of which from 3 to 6 feet is visible above water, is exposed on the left bank of the stream, dipping north-east at about 50°. Mr. Mitchell, Assistant Engineer, is at present engaged in cutting a path to the spot and opening pits at a short distance from the river bank, in order to discover the extent of the bed. The density of the jungle renders it impossible to see how far the bed extends without this being done, but I think that enough stone can certainly be raised without much difficulty to supply the wants of, at any rate, the Naga Hills. It will only be possible to obtain the stone during the cold weather, as the pits will be under water during the rains. The limestone is similar to that seen below the falls on the Námbar, and it is possible that it may be found on the low ridge separating the Doigrung from the Námbar, in which case quarries, not liable to be flooded every year, might be opened in it. In fact, it is not improbable that sufficient limestone may be obtained here to supply the wants of a large part of Upper Assam. An assay of the Doigrung limestone gave the following result:—

Carbonate of lime	72·97
„ „ magnesia	7·33
Oxide of iron, alumina and magnesia	9·00
Insoluble	10·70
	100·00

Homotaxis, *as illustrated from* Indian Formations *by* W. T. BLANFORD, F.R.S., Sec. G.S., F.R.G.S.[1]

In commencing an address to the Geological Section of the British Association on the first occasion on which that body has met outside of the British Islands, I feel much difficulty. Amongst the eminent geologists who have filled the post which you have done me the honour of calling upon me to occupy for the present year, there are several who would have been able, from their knowledge of both European and American geology, to treat with authority of the many points of interest elicited by comparison of geological phenomena on opposite sides of the Atlantic Ocean. My own experience has been chiefly derived from the distant continent of Asia, and I have not that intimate acquaintance with the geology of Europe, nor that knowledge of the progress of geological research in America, which would justify my entering upon any comparison of the two continents. It has, however, occurred to me that amongst the questions of wide importance connected with the correlation of strata in distant parts of the world, there is one to which some interesting contributions have been made by the work of the Geological Survey of India, and by the geologists of Australia and South Africa; and that a short time might be profitably devoted to a consideration of a few

[1] This is a reprint of Mr. Blanford's address as President of the Geological Section of the British Association, at Montreal, 1884.

remarkable exceptions to the rule that similarity of faunas and floras in fossiliferous formations throughout the surface of the world implies identity of geological age.

It has probably occurred to other geologists here present, as it has to myself, to be engaged in examining a country the geology of which was absolutely unknown, and to feel the satisfaction that attends the first discovery of a characteristic fossil form. A clue is at once afforded to the geology of the region; one horizon at least is believed to be determined, and from this horizon it is possible to work upwards and downwards until others are found.

It is, therefore, of special importance to those engaged in geological exploration to satisfy themselves whether the conclusion is correct that identity, or close specific similarity, amongst fossil forms, is a proof that the beds containing them are of the same geological age. It has been pointed out by some of the most careful thinkers, and especially by Forbes and Huxley, that a species requires time to spread from one area to another; that, in numerous cases, a migratory specific form must flourish in the region to which it has migrated, after it has died out in its original birth-place; and that the presence of the same species in two deposits at distant localities may rather tend to indicate that both were not formed simultaneously. Huxley, as is well known, invented the term 'homotaxis' to express the relations between such beds, and to avoid the possibly misleading expressions 'geological synchronism,' and 'contemporaneous origin.'

Despite such cautions, however, it still appears to be generally assumed by palæontologists that similarity between faunas and floras is evidence of their belonging to the same geological period; that the geological age of any formation, whether marine, fresh-water, or subaërial, can be determined by a comparison of its organic remains with those of other deposits, no matter how distant, of which the position in the geological sequence is ascertained: in short, that homotaxis of marine, fresh-water, and terrestrial forms implies geological synchronism.

That, as a general rule, homotaxis affords evidence that beds exhibiting it belong approximately to the same geological period, appears supported by a large amount of evidence. But there are some startling exceptions. I propose to notice a few typical instances, several of them Indian, in which the system of determining the age of various formations by the fauna or flora has led to contradictory results, before attempting to show wherein the source of the error appears to lie. Nothing would be gained and much time would be lost by entering upon the details of all the cases known, even if I were able to give authentic particulars, which is doubtful. It will be sufficient to cite some characteristic examples, concerning the details of which satisfactory evidence is forthcoming.

Pikermi Beds.—There are but few fossiliferous deposits on the face of the earth that have attracted more attention than the Pikermi beds of Greece. In one of the most classical and famous sites of the world, a few miles east of Athens, just where

> The mountains look on Marathon,
> And Marathon looks on the sea,

some red, silty beds occur, abounding in vertebrate remains. Some of the bones were described by Wagner and others, but for a complete account of the fauna we

are indebted to Professor Albert Gaudry, who has himself collected by far the greater portion of the remains hitherto procured. The following is a list of the genera determined; it is unnecessary to give the specific names :—

MAMMALIA.

PRIMATES.—*Mesopithecus*, 1 sp.
CARNIVORA.—*Simocyon*, 1; *Mustela*, 1; *Promephitis*, 1; *Ictitherium*, 3; *Hyænarctus*, 1; *Hyæna*, 2; *Hyænictis*, 1; *Felis* 4; *Machærodus*, 1.
PROBOSCIDEA.—*Mastodon*, 2; *Dinotherium*, 1.
UNGULATA.—*Chalicotherium*, 1; *Rhinoceros*, 3; *Acerotherium*, 1; *Leptodon*, 1; *Hipparion*, 1; *Sus*, 1; *Camelopardalis*, 1; *Helladotherium*, 1; *Orasius*, 1; *Palæotragus*, 1; *Protragelaphus*, 1; *Palæoryx*, 2; *Tragocerus*, 2; *Palæoreas*, 1; *Antidorcas* (?), 1; *Gazella*, 1; *Antilope*, 3; *Dremotherium*, 2; *Cervus*, 1.
RODENTIA.—*Mus* (*Acomys*), 1; *Hystrix*, 1.
EDENTATA.—*Ancylotherium*, 1.

AVES.

Phasianus, 1; *Gallus*, 1; *Gen. gallinac. indet.*, 1; *Grus*, 1; *Gen. ciconidar. indet*, 1.

REPTILIA.

Testudo, 1; *Varanus*, 1.

Of mammalia alone there are known from this deposit 33 genera, of which 22 are extinct, and 47 species.

Now, this fauna is almost invariably in European works quoted as Miocene. Of the species found no less than 14—*Simocyon diaphorus*, *Ictitherium robustum*, *I. hipparionum*, *Hyæna eximia*, *Hyænictis græca*, *Machærodus cultridens*, *Mastodon turicensis*, *Dinotherium giganteum*, *Rhinoceros schleiermacheri*, *Hipparion gracile*, *Sus erymanthius*, *Helladotherium duvernoyi*, *Tragocerus amaltheus*, and *Gazella brevicornis*—are met with in other European deposits assigned to the Miocene period. It is true that one of these deposits at least—that of Eppelsheim—has been shown on stratigraphical grounds to be much more probably Pliocene than Miocene, and the position of other deposits has been determined by the kind of argument which, as I shall show, has proved misleading in the case of Pikermi itself. Nevertheless so general is the consensus of opinion amongst palæontologists, that the beds with *Hipparion* at Pikermi and elsewhere are quoted as especially included in the Miocene system by the French Committee of the International Geological Congress. Amongst English writers the Miocene age of the Pikermi beds appears generally admitted, as by Mr. Wallace,[1] Professor Boyd Dawkins,[2] Mr. E. T. Newton,[3] and many others. Professor Gaudry himself is much more cautious; he classes the fauna as intermediate between Pliocene and Miocene, and only relegates it to Upper Miocene because that is the position assigned by other palæontologists to beds containing remains of *Hipparion*. However, in his subsequent works Professor Gaudry has classed the Pikermi fauna as Miocene.

Now, the lowest of the beds with the vertebrate fauna at Pikermi were by Professor Gaudry himself found to be interstratified with a band of grey conglo-

[1] *Geographical Distribution of Animals*, i. p. 115.
[2] *Q. J. G. S.* 1880, p. 389.
[3] *Q. J. G. S.* 1884, pp. 284, 287, &c.

merate containing four characteristic *marine* Pliocene mollusca—*Pecten benedictus*, Lam.; *Spondylus gœderopus*, L.; *Ostrea lamellosa*, Brocchi; and *O. undata*, Lam. It should be remembered that the Pliocene fauna of the Mediterranean area is the richest and most typical in Europe, and is as well known as any geological fauna in the world. It should also be remembered that the Pliocene beds are well developed in Greece at other localities besides Pikermi. Professor Gaudry especially points out that the vertebrate remains, supposed to be those of Miocene animals, are deposited in a stratum overlying a marine bed of undoubted Pliocene age, and he proposes the following hypothesis to account for the presence of Miocene fossils in a Pliocene stratum. The remains found at Pikermi are, he thinks, those of animals that inhabited the extensive plains which in Miocene times extended over a considerable proportion of the area now occupied by the Eastern Mediterranean and which united Greece to Asia; the plains were broken up by the dislocations that took place at the close of the Miocene period, and the animals escaped to the mountains, where they died for want of space and of food. Their bones were subsequently washed down by the streams from the hills and buried in the Pliocene deposits of Pikermi.

Professor Gaudry evidently has no very profound faith in this hypothesis, and it is unnecessary to refute it at length. One fact is sufficient to show that it is untenable. However sudden may have been the cataclysm that is supposed to have broken up the Miocene plains of Attica, a very long period, measured in years, must have elapsed before the Pliocene marine fauna could have established itself. Now, the bones of mammals exposed on the surface decay rapidly; the teeth break up, the bones become brittle. It is doubtful if bones that had been exposed for only five or six years would be washed down by a stream without being broken into fragments; the teeth especially would split to pieces. The condition of the Pikermi fossils proves, I think, that they must have been buried very soon after the animals died, that they were not exposed on the surface for any length of time, and that they could not have been washed out of an earlier formation, and it appears to me incredible that the Pikermi mammals were not contemporary with the Pliocene mollusca that occur in the same beds. In short, I cannot but conclude that the Pikermi mammals were Pliocene and not Miocene.

This view is entirely in accordance with the opinions of Theodor Fuchs.[1] He has given a good account of the geology of various places in Greece, and amongst others of Pikermi. He found, again, the conglomerate with Pliocene marine mollusca interstratified with the basal portion of the mammaliferous beds, and he concludes[2] that not only is it clear that these mammaliferous beds are of Pliocene age, but that a comparison of their geological position with that of the marine strata of the Piræus proves that the Pikermi beds occupy a very high position in the Pliocene, and are probably the highest portion of the system as developed in the neighbourhood.

Fuchs also shows that the principal Pliocene mammaliferous beds are of later date than the typical Pliocene (Subapennine) beds of Italy, and that some mammalia found associated with the latter comprise forms identical with those of the

[1] *Denkschr. K. Acad. Wiss. Wien*, 1877, xxxvii. 2e Abth. p. 1.
[2] *L. c.*, p. 30.

Pikermi beds. In subsequent papers on the age of the beds containing *Hipparion* the same writer shows reasons for classing these strata in Italy, France (Vaucluse), and Germany as intermediate between Miocene and Pliocene. This leaves the difficulty unsolved, for he had shown the Pikermi beds to be high in the Pliocene system. They rest unconformably upon certain fresh-water limestones, clays, &c., containing plants and mollusca, and classed by Gaudry as Miocene, but by Fuchs as Pliocene. Thus by both writers the mammaliferous beds of Pikermi are referred to a considerably later geological horizon than those containing identical species in other parts of Europe.

It would require too much time to enter into the still more difficult question of the various plant-bearing beds in different parts of Europe and in Greenland containing a flora classed by Heer and others as Miocene. Gardner has given reasons for considering the Greenland beds Eocene; Fuchs, as just stated, is of opinion that the Greek beds are Pliocene. One point should be noted, that the more northern flora is considered older than the more southern, and it will be remarked that the same observation applies to the supposed Upper Miocene fauna of France and Germany and the Pikermi fauna of Greece.

Siwalik.—The next instance which I shall describe is another of the most important fossil mammalian faunas of the Old World, that found in the Upper Tertiary beds that fringe the Himalayas on the south. The name applied to this fauna is taken from one of the localities in which it was first found, the Siwalik (correctly, I believe, Shib-wála) hills, between the Deyra Dun and the plains north by east of Delhi. Bones of Siwalik mammalia are found, however, throughout a considerable area of the Northern Punjab.

The Siwalik fauna has been worked out, chiefly by Falconer and Lydekker, the last-named being still engaged in describing the species. The following is a list of the genera found in the true Siwalik beds[1] :—

MAMMALIA.

PRIMATES—*Palæopithecus*, 1 sp.; *Macacus*, 2; *Semnopithecus*, 1; *Cynocephalus*, 2.

CARNIVORA.—*Mustela*, 1; *Mellivora*, 2; *Mellivorodon*, 1; *Lutra* 3; *Hyænodon*, 1; *Ursus*, 1; *Hyænarctus*, 3; *Canis*, 2; *Viverra*, 2; *Hyæna*, 4; *Hyænictis*, 1; *Lepthyæna*, 1; *Æluropsis*, 1; *Ælurogale*, 1; *Felis*, 5; *Machærodus*, 2.

PROBOSCIDEA—*Elephas*, 6 (*Euelephas*, 1; *Loxodon*, 1; *Stegodon*, 4); *Mastodon*, 5.

UNGULATA.—*Chalicotherium*, 1; *Rhinoceros*, 3; *Equus*, 1; *Hipparion*, 2; *Hippopotamus*, 1; *Tetraconodon*, 1; *Sus*, 5; *Hippohyus*, 1; *Sanitherium*, 1; *Merycopotamus*, 1; *Cervus*, 3; *Dorcatherium*, 2; *Tragulus*, 1; *Moschus*, 1; *Propalæomeryx*, 1; *Camelopardalis*, 1; *Helladotherium*, 1; *Hydaspitherium*, 2; *Sivatherium*, 1; *Alcelaphus*, 1; *Gazella*, 1; *Antilope*, 2; *Oreas*, (?), 1; *Palæoryx*, (?), 1; *Portax* 1; *Hemibos*, 3; *Leptobos*, 1; *Bubalus*, 2; *Bison*, 1; *Bos*, 3; *Bucapra*, 1; *Capra*, 2; *Ovis*, 1; *Camelus*, 1.

RODENTIA.—*Mus* (*Nesokia*), 1; *Rhyzomys*, 1; *Hystrix*, 1; *Lepus*, 1.

AVES.

Graculus, 1; *Pelecanus*, 2; *Leptoptila*, 1; *Gen. non det. ciconid.*, 1; *Mergus*, 1; *Struthio*, 1; *Dromæus*, 1; *Gen. non det. struth.*, 1.

[1] Lydekker, *J. A. S. B.* 1880, pt. 2, p. 34; *Palæontologia Indica*, ser. x. vols. i, ii, iii; *Records, Geological Survey of India*, 1883, p. 81. I am indebted to Mr. Lydekker for some unpublished additions, and for aid in compiling both the Siwalik and Pikermi lists.

REPTILIA.

CROCODILIA—*Crocodilus*, 1; *Gharialis*, 3.
LACERTILIA—*Varanus*, 1.
CHELONIA—*Colossochelys*, 1; *Testudo*, 1; *Bellia*, 2; *Damonia*, 1; *Emys*, 1; *Cautleya*, 1; *Pangshura*, 1; *Emyda*, 1; *Trionyx*, 1.

PISCES.

Bagarius, 1.

Now, until within the last few years, this fauna was classed as Miocene by European palæontologists as unhesitatingly as the Pikermi fauna still is, and in the majority of European geological works, despite the unanimous opinion of all the geologists who are acquainted with the sub-Himalayan beds, the Siwalik fauna is still called Miocene. The geologists of the Indian Survey, however, classed the fossiliferous Siwaliks as Pliocene, on both geological and biological grounds. With regard to the latter, not only does the fauna comprise a large number of existing genera of mammals, such as *Macacus*, *Semnopithecus*, *Ursus*, *Elephas* (*Euelephas*), *Equus*, *Hippopotamus*, *Camelopardalis*, *Bos*, *Hystrix*, *Mus*, and especially *Mellivora*, *Meles*, *Capra*, *Ovis*, *Camelus*, and *Rhizomys*, but three out of six or seven clearly determined species of reptiles, viz.—*Crocodilus palustris*, *Gharialis gangeticus*, and *Pangshura tectum*—are living forms now inhabiting Northern India, whilst all the known land and fresh-water mollusca, with one possible exception, are recent species.

These data, however, although very important and very cogent, belong to a class of facts that have led, I believe, in other cases to erroneous conclusions. The geological evidence is far more satisfactory, and it is not liable to the same objection.

The whole Siwalik fauna, as given above, has been obtained from the upper beds of a great sequence or system. Beneath the fossiliferous strata at the base of the North-West Himalaya there is an immense thickness, amounting in places to many thousands of feet, of sandstones, clays, and other beds, from none of which recognisable fossils have been procured. The first beds of known age that are met with below the mammaliferous Siwaliks are marine rocks belonging to the Eocene system.

But as we pass from the Himalayas to the south-west, along the western frontier of India in the Punjab, and onwards to the south in Sind, the same Siwalik system can be traced almost without interruption, and in the last-named country the lower unfossiliferous strata become intercalated with fossiliferous beds. In Sind the upper Siwaliks no longer yield any vertebrate remains that can be identified, but far below the horizon of the Siwalik fauna a few bones have been found, and the following mammals have been identified[1] :—

CARNIVORA—*Amphicyon palæindicus.*
PROBOSCIDEA—*Mastodon latidens*, *M. perimensis*, *M. falconeri*, *M. pandionis*, *M. angustidens*, *Dinotherium indicum*, *D. sindiense*, *D. pentepotamiæ.*
UNGULATA—*Rhinoceros sivalensis*, var. *intermedius*, *Acerotherium perimense*, *A. blanfordi*, *Sus hysudricus*, *Hyotherium sindiense*, *Anthracotherium silistrense*, *A. hyopotamoides*,

[1] *Pal. Ind.*, ser. x; *Rec.*, *Geol. Surv. Ind.*, 1883, pp. 82, &c.

Hyopotamus palæindicus, H. giganteus, Hemimeryx blanfordi, Sivameryx sindiensis Agriochœrus sp. Dorcatherium majus, D. minus.
EDENTATA—*Manis* (?) *sindiensis.*

Although about one-third of the species above named have been found also in the upper Siwalik beds of the Punjab, it is unnecessary to point out in detail why the lower Siwalik fauna is clearly by far the older of the two. The absence of such living genera as *Elephas, Bos, Equus,* &c., and the presence of so many typically Middle Tertiary forms, such as *Dinotherium, Anthracotherium,* and *Hyopotamus,* shows a great change. The mollusca tell the same tale. All the forms known from the upper Siwaliks, with one exception, are recent species of land and fresh-water shells now living in the area. Of seven fresh-water mollusca[1] found associated with the lower Siwaliks, none appears to be identical with any living species, and only two are allied, one closely, the other more remotely, to forms now met with in Burma 30° of longitude further east.

Before proceeding with the argument it is as well to call attention to the very important fact just mentioned. It has been asserted over and over again that species of *mammalia* are peculiarly short-lived, far more so than those of *mollusca.* In this case, so far as the evidence extends at present, one-third of the species of *mammalia* survived the changes that took place, whereas not a single mollusk is found both in the upper and lower Siwaliks. It should be remembered that the recent molluscan river fauna of this part of India is very poor in species, and that we probably know a considerable proportion of that existing in Siwalik times.

The geological age of the lower Siwalik beds of Sind is shown by their passing downwards into marine fossiliferous beds, known as the Gáj group, of Miocene age, the following being the section of Tertiary strata exposed in the hills west of the Indus:—

		Ft.	
SIWALIK or MANCHAR	Upper	5,000 unfossiliferous .	Pliocene
	Lower	3,000 to 5,000 fossiliferous	Upper Miocene or Lower Pliocene
GAJ .		1,000 to 1,500 fossiliferous	Miocene
NARI .	Upper	4,000 to 6,000 unfossiliferous	Lower Miocene
	Lower	100 to 1,500 fossiliferous	Oligocene
KHIRTHAR	Upper	500 to 3,000 fossiliferous	Eocene
	Lower	6,000 fossiliferous .	

Clearly the lower Siwaliks of Sind cannot be older than Upper Miocene; therefore the Upper Siwaliks, which are shown by both biological and geological evidence to be of much later date, must be Pliocene.

Gondwana system of India.—In the peninsula of India there is remarkable deficiency of marine formations. Except in the neighbourhood of the coast or of the Indus valley there is, with one exception (some cretaceous rocks in the Nerbudda valley), not a single marine deposit known south of the great Gangetic plain. But in Bengal and Central India, over extensive tracts of country, a great sequence of fresh-water beds, probably of fluviatile origin, is found, to which the name of Gondwána system has been applied. The uppermost beds of this

[1] *Mem., Geol. Surv. Ind.,* vol. xx, pt. 2, p. 129.

system, in Cutch to the westward, and near the mouth of the Godávari to the eastward, are interstratified with marine beds containing fossils of the highest Jurassic (Portlandian and Tithonian) types.

The Gondwána system is a true system in the sense that all the series comprised are closely connected with each other by both biological and physical characters, but it represents in all probability a much longer period of geological time than do any of the typical European systems. The highest members, as already stated, are interstratified with marine beds containing uppermost Jurassic fossils. The age of the lowest members is less definitely determined, and has been by different writers classed in various series from middle Carboniferous to Middle Jurassic. The Gondwána beds from top to bottom are of unusual interest on account of the extraordinary conflict of palæontological evidence that they present.

The subdivisions of the Gondwána system are numerous, and in the upper portions especially the series and stages are different in almost every tract where the rocks are found. The following are the subdivisions of most importance on account of their fauna and flora, or of their geological relations.

Upper Gondwána	Cutch and Jabalpur.		
	Kota Maleri.		
	Rajmahal.		
Lower Gondwána	Panchet.		
	Damuda	Ránigánj and Kámthi.	
		Barákar.	
	Karharbári.		
	Tálchir.		

The upper Gondwánas, where best developed, attain a thickness of 11,000 feet and the lower of 13,000 feet.

The Tálchir and Barákar subdivisions are far more generally present than any of the others.

Tálchir.—The Tálchir beds consist of fine silty shales and fine soft sandstone. Very few fossils have been found in them, and these few recur almost without exception in the Karharbári stage. The Tálchirs are principally remarkable for the frequent occurrence of large boulders, chiefly of metamorphic rocks. These boulders are sometimes of great size, 6 feet or more across, 3 to 4 feet being a common diameter; all are rounded, and they are generally embedded in fine silt.

Karharbári.—The Karharbári beds are found in but few localities. They contain some coal-seams, and the following plants have been met with[1]:—

CONIFERÆ.—*Euryphyllum*, 1 sp.; *Voltzia*, 1; *Albertia*, 1; *Samaropsis*, 1.
CYCADEACEÆ.—*Glossozamites*, 1; *Noeggerathiopsis*, 1.
FILICES.—*Neuropteris*, 1; *Glossopteris*, 4; *Gangamopteris*, 4; *Sagenopteris*, 1.
EQUISETACEÆ.—*Schizoneura*, 2; *Vertebraria*, 1.

The most abundant form is a *Gangamopteris*. The *Voltzia* (*V. heterophylla*) is a characteristic Lower Triassic (Bunter) form in Europe. The *Neuropteris* and *Albertia* are also nearly related to the Lower Triassic forms. The species of *Gangamopteris*, *Glossopteris*, *Vertebraria*, and *Noeggerathiopsis* are allied to forms found in Australian strata.

[1] Feistmantel: *Palæontologia Indica*, ser. xii. vol. iii.

Damuda.—The Damuda series consists of sandstones and shales with coal-beds; the floras of the different subdivisions present but few differences, and the following is the list of plants found[1]:—

CONIFERÆ.—*Rhipidopsis*, 1 sp., *Voltzia*, 1; *Samaropsis*, 1; *Cyclopitys*, 1.
CYCADEACEÆ.—*Pterophyllum*, 2; *Anomozamites*, 1; *Noeggerathiopsis*, 3.
FILICES.—*Sphenopteris*, 1; *Dicksonia*, 1; *Alethopteris*, 4; *Pecopteris*, 1; *Merianopteris*, 1; *Macrotæniopteris*, 2; *Palæovittaria*, 1; *Angiopteridium*, 2; *Glossopteris*, 19; *Gangamopteris*, 7; *Belemnopteris*, 1; *Anthrophyopsis*, 1; *Dictyopteridium*, 1; *Sagenopteris*, 4; *Actinopteris*, 1.
EQUISETACEÆ.—*Schizoneura*, 1; *Phyllotheca*, 3; *Trizygia*, 1; *Vertebaria*, 1.

The only remains of animals hitherto recorded are an *Estheria* and two Labyrinthodonts, *Branchyops laticeps* and an undescribed form formerly referred to *Archegosaurus*. The only European genus allied to *Branchyops* is of oolitic age.

The most abundant of the above-named fossils are *Glossopteris* and *Vertebraria*. With the exception of *Noeggerathiopsis* all the cycads and conifers are of excessive rarity. More than one-half of the species known are ferns with simple undivided fronds and anastomosing venation.

For many years European palæontologists generally classed this flora as Jurassic.[2] This was the view accepted by De Zigno and Schimper, and, though with more hesitation, by Bunbury. The species of *Phyllotheca*, *Alethopteris* (or *Pecopteris*), and *Glossopteris* (allied to *Sagenopteris*) were considered to exhibit marked Jurassic affinities. It was generally admitted that the Damuda flora resembles that of the Australian coal-measures (to which I shall refer presently) more than it does that from any known European formation; but the Australian plants were also classed as Jurassic. There is no reason for supposing that the more recent discoveries of Damuda plants would have modified this view; the identification of such forms as true *Sagenopteris* and the cycads *Pterophyllum* and *Anomozamites* would assuredly have been held to confirm the Jurassic age of the beds. So far as European fossil plants are concerned, the Damuda flora resembles that of the middle or lower Jurassics more than any other.

One form, it is true, the *Schizoneura*, is closely allied to *S. paradoxa* from the Bunter or lower Trias of Europe. Other plants have Rhætic affinities. But the connections with the Triassic flora do not seem nearly equal to those shown with Jurassic plants, and the reason that the Damuda flora has been classed as probably Triassic must be sought in the impossibility of considering it newer,[3] if the next overlying stage is classed as Upper Trias or Rhætic, and in the close affinity with the underlying Karharbári beds, which contain several Lower Triassic types.

Panchet.—The uppermost series of the lower Gondwánas consists chiefly of sandstone, and fossils are rare. The most interesting are remains of *Reptilia* and

[1] *Pal. Ind.*, ser. ii. xi. xii. vol. iii.
[2] De Zigno: *Flora Fossilis Form. Ool.* pp. 50, 53; Schimper; *Traité de Paléontologie Végétale* i. p. 645; Bunbury; *Q. J. G. S.* 1861, xvii. p. 350.
[3] Feistmantel; *Pal. Ind.*, ser. xii. vol. iii pp. 57, 129, &c.

Amphibia. The following is a list of the fossil animals and plants corrected to the present time :—

ANIMALS.

REPTILIA.

DINOSAURIA.—*Ancistrodon*, 1 sp.
DICYNODONTIA.—*Dicynodon* (*Ptychognathus*), 2.

AMPHIBIA.

LABYRINTHODONTIA.—*Gonioglyptus*, 2; *Glyptognathus*, 1; *Pachygonia*, 1.

CRUSTACEA.

Estheria, 1.

PLANTS.

CONIFERÆ.—*Samaropsis*, 1.
FILICES.—*Pecopteris*, 1; *Cyclopteris*, 1; *Thinnfeldia*, 1; *Oleandridium*, 1; *Glossopteris*, 3.
EQUISETACEÆ.—*Schizoneura*, 1.

The *Schizoneura* and the three species of *Glossopteris* are considered the same as Damuda forms. But with them are found two European Rhætic species, *Pecopteris concinna* and *Cyclopteris pachyrachis*. The *Oleandridium* is also closely allied to a European Rhætic form, and may be identical. The flora may thus be classed as typically Rhætic.

All the genera of *Labyrinthodonts* named are peculiar; their nearest European allies are chiefly Triassic. *Dicynodontia* are only known with certainty from India and South Africa, but some forms believed to be nearly allied have been described from the Ural mountains.[1] These fossils were obtained from rocks now referred to the Permian.[2]

Upper Gondwánas.—The different series of the lower Gondwánas are found in the same area resting one upon the other, so that the sequence is determined geologically. This is not the case with the upper Gondwána groups; their most fossiliferous representatives are found in different parts of the country, and the relations to each other are mainly inferred from palæobotanical data. Although, therefore, it is probable that the Rájmaháls are older than the Cutch and Jabalpur beds, and that the Kota-Maleri strata are of intermediate age, it is quite possible that two or more of these series may have been contemporaneously formed in regions with a different flora.

Rájmahál.—The comparatively rich flora of the lowest upper Gondwána series is contained in beds interstratified with basaltic lava-flows of the fissure-eruption type. The following are the genera[3] of plants found :—

CONIFERÆ.—*Palissya*, 2 sp.; *Cunninghamites*, 1; *Chirolepis*, 2; *Araucarites*, 1; *Echinostrobus*, 1.
CYCADEACEÆ.—*Pterophyllum*, 9; *Ptilophyllum*, 1; *Otozamites*, 3; *Zamites*, 1; *Dictyozamites*, 1; *Cycadites*, 2; *Williamsonia*, 2; *Cycadinocarpus*, 1.
FILICES.—*Eremopteris*, 2; *Davallioides*, 1; *Dicksonia*, 1; *Hymenophyllites*, 1; *Cylopteris*, 1; *Thinnfeldia*, 1; *Gleichenia*, 1; *Alethopteris*, 1; *Asplenites*, 1; *Pecopteris*, 1; *Macrotæniopteris*, 4; *Angiopteridium*, 3; *Danæopsis*, 1; *Rhizomopteris*, 1.
EQUISETACEÆ.—*Equisetum*.

[1] Huxley; *Q. J. G. S.*, xxvi., p. 48.
[2] Twelvetrees; *Q. J. G. S.*, xxxviii. p. 500.
[3] *Pal. Ind.* ser ii.; Feistmantel; *Records*, *G. S. I.*, ix, p. 39.

The marked change from the lower Gondwána floras is visible at a glance; not a single species is common to both, most of the genera are distinct, and the difference is even greater when the commonest plants are compared. In the lower Gondwánas the prevalent forms are *Equisetaceæ* and ferns of the *Glossopteris* type, whilst in the Rájmahál flora cycads are by far more abundant than any other plants. The whole assemblage, moreover, is more nearly allied than are any of those in the lower Gondwána beds to European Mesozoic floras.

Of the Rájmahál plants[1] about fifteen are allied to Rhætic European forms, three to Liassic or lower Jurassic (two of these having also Rhætic affinities), and six to Middle Jurassic (two having Rhætic relations as well). The flora must therefore as a whole on purely palæontological grounds be classed as Rhætic.

Kota-Maleri.—The deposits belonging to this series are found in the Godávari valley at a considerable distance from the Rájmahál hills in Bengal, the locality for the Rájmahál flora. Both Rájmahál and Kota-Maleri beds overlie rocks of the Damuda series. It is not quite clear whether the Kota beds, which contain fish, insects, and crustaceans, and the Maleri beds, in which remains of fish, reptiles, and plants are found, are interstratified, or whether the Kota beds overlie those of Maleri. That the two are closely connected is generally admitted.

From the Maleri beds the following remains have been recorded.—

ANIMALS.

REPTILIA.—*Hyperodapedon, 1; Parasuchus, 1.*
PISCES.—*Ceratodus, 3.*

PLANTS.

CONIFERÆ.—*Palissya, 2; Chirolepis, 1; Araucarites, 1.*
CYCADEACEÆ.—*Ptilophyllum, 1; Cycadites, 1.*
FILICES.—*Angiopteridium*, 1.

From the Kota fresh-water limestone 9 species of ganoid fish—*viz.* 5 of *Lepidotus*, 3 of *Tetragonolepis*, and 1 of *Dapedius*—have been described. An *Estheria*, a *Candona*, and some insects have also been found. The fish[2] are Liassic forms.

The reptilia of the Maleri beds are, on the other hand, Triassic[3] and closely allied to Keuper forms. *Ceratodus* is chiefly Triassic (Keuper and Rhætic). The plants show relations with both the Rájmahál and Jabalpur floras, and, as the palæontological relations to beds in the same country are considered far higher in importance than those to deposits in distance regions, the Kota-Maleri beds are classed as intermediate between the Rájmahál and Jabalpur epochs.

Cutch and Jabalpur.—Jabalpur beds are found in Central India to the south of the Nerbudda valley, and form the highest true Gondwána beds. The Cutch beds, as already mentioned, are found interstratified with marine deposits of uppermost Jurassic age far to the westward, a little east of the mouths of the river Indus. The similarity of the plant-remains in the two series has caused them to be classed together, but it is not certain that they are really of contemporaneous origin.

[1] Feistmantel, *Pal. Ind.*, ser. ii., pp. 143—187; *Man. Geol. Ind.*, p. 145.
[2] *Pal. Ind.*, ser. iv., pt. 2.
[3] *Q. J. G. S.* 1869, pp. 138, 152, &c.; 1875, p. 427; *Pal. Ind.*, ser. iv., pt. 3; *Man. Geol. Ind.* p. 151.

The following is a list of the Jabalpur plants[1] :—

CONIFERÆ.—*Palissya*, 2; *Araucarites*, 1; *Echinostrobus*, 2; *Brachyphyllum*, 1; *Taxites*, 1; *Gingko*, 1; *Phœnicopsis*, 1; *Czekanowskia*, 1.

CYCADEACEÆ.—*Pterophyllum*, 1; *Ptilophyllum*, 2; *Podozamites* 3; *Otozamites*, 4; *Williamsonia*, 1; *Cycadites*, 1.

FILICES.—*Sphenopteris*, 1; *Dicksonia*, 1; *Alethopteris*, 3; *Macrotæniopteris*, 1; *Glossopteris*, 1; *Sagenopteris*, 1.

Of these thirty species nine are regarded either as identical with forms found in the Middle Jurassic (Lower Oolitic) of England or as closely allied.

The Cutch plants belong to the following genera[2] :—

CONIFERÆ.—*Palissya*, 3 sp.; *Pachyphyllum*, 1; *Echinostrobus*, 1; *Araucarites*, 1.

CYCADEACEÆ.—*Ptilophyllum*, 3; *Otozamites*, 3; *Cycadites*, 1; *Williamsonia*, 1; *Cycadolepis*, 1.

FILICES.—*Oleandridium*, 1; *Tæniopteris*, 1; *Alethopteris*, 1; *Pecopteris*, 1; *Pachypteris* 2; *Actinopteris*, 1.

Of the twenty-two species enumerated, four are identified with specific forms found in the Middle Jurassic of Yorkshire, and seven others are closely allied. The Cutch and Jabalpur beds, in short, are intimately related with European fossil floras.

One interesting fact should be mentioned. The Cutch flora occurs in the upper part of the Umia beds, the lower beds of which contain *cephalopoda* of Portlandian and Tithonian forms. In a lower subdivision of the Cutch Jurassic rocks, the Katrol group, shown by numerous Ammonites to be allied to Kimmeridge and upper Oxford beds of Western Europe, four species of plants have been found, of which three are met with in the Umia beds, and the fourth, an English oolitic form, in the Jabalpur series. This evidence seems in favour of the view that the flora underwent change more slowly than the marine fauna.

It will be as well, before leaving the subject of the Gondwána groups, to show in a tabular form the geological age assigned to the flora and fauna of each separately, on the evidence afforded by comparison with the plants and animals known from European formations.

		PLANTS.	ANIMALS.
Upper Gondwána	Cutch	Middle Jurassic	Uppermost Jurassic ? Neocomian (marine).
	Jabalpur	Middle Jurassic	—
	Kota	—	Lower Jurassic (Liassic).
	Maleri	Middle or Lower Jurassic	Triassic.
	Rájmahál	Rhætic	—
Lower Gondwána	Panchet	Rhætic	Triassic or Permian.
	Damuda	Middle Jurassic	Middle Jurassic ?
	Karharbári, Talchir	Lower Triassic	—

[1] *Pal. Ind.*, ser. xi., pt. 2.

[2] *Pal. Ind.*, ser. xi., pt. 1.

Flora of Tonquin.—Quite recently M. Zeiller has described a series of plants from some coal-bearing beds in Tonquin.[1] This flora is very extraordinary in every respect. It consists of 22 species, and contains only two peculiar forms ten, or nearly one-half, are European species found in the lower Lias or Rhætic; whilst of the remaining ten, five are Damuda forms—*Noeggerathiopsis hislopi, Macrotæniopteris feddeni, Palæovittaria kurzi, Glossopteris browniana,* and *Phyllotheca indica,* one species being common to the Newcastle beds and Carboniferous flora of Australia and two others closely allied to the forms there occurring. The other five are said to be Rájmahál forms, four *Tæniopteris* or *Angiopteridium* and an *Otozamites.* M. Zeiller unhesitatingly classes the Tonquin beds as Rhætic. It is most singular that these coal-beds, although more distant from Europe by 18° of longitude than either the Damuda or Rájmahál beds of India, contain a larger proportion of European fossil species than any known Indian plant-beds; whilst the association in the same strata of upper and lower Gondwána forms, if well ascertained, shows how hopeless is the attempt to classify these deposits by plant evidence alone.

Australian Coal-Measures and Associated Beds.—In the notice of the lower Gondwána floras of India it was observed that there was a great resemblance between some of them and those found in certain beds of Australia. These latter present even a more remarkable instance of homotaxial perversity than do the Indian rocks. The Australian plant-bearing beds are found in Eastern and Southern Australia, Queensland, and Tasmania. For a knowledge of the geology of the country we are chiefly indebted to the writings of the late Mr. Clarke,[2] whilst the flora has been worked out by McCoy, Dana, Carruthers, and Feistmantel, the last having recently published a much more complete account than was previously available.[3]

The following are the fresh-water or subaërial beds of Australia, according to the latest classification:—

6. Clarence River beds, New South Wales (Mesozoic carbonaceous of Queensland, Victoria, and Tasmania).
5. Wianamatta beds, N. S. Wales.
4. Hawkesbury beds, N. S. Wales (Bacchus Marsh sandstones, Victoria).
3. Newcastle beds, N. S. Wales.
2. Lower Coal-Measures with marine layers interstratified, N. S. Wales.
1. Lower Carboniferous beds, N. S. Wales.

To a still lower horizon probably belong some beds in Queensland, containing *Lepidodendron nothum* and *Cyclostigma.* They are considered Devonian by Carruthers, and there are some ancient plant-beds in Victoria that may be of the same period.

1. *Lower Carboniferous Beds.*—These underlie the beds with a Carboniferous marine fauna. The localities given are Smith's Creek, near Stroud, Port Stephens, and Arowa. The following plants are enumerated:—

LYCOPODIACEÆ.—*Cyclostigma,* 1 sp.; *Lepidodendron,* 2 *or* 3; *Knorria,* 1.

[1] *Bull. Soc. Géol.,* ser. iii., vol. xi., p. 456.

[2] *Q. J. G. S.* 1861, p. 354, and *Remarks on the Sedimentary Formations of New South Wales,* 1878, besides numerous other works.

[3] *Palæontographica.*—*Pal. u. mes. Flora im östl. Australien,* 1878-79.

FILICES.—*Rhacopteris*, 4; *Archæopteris*, 2 (?); *Glossopteris*, 1.
EQUISETACEÆ.—*Calamites*, 2; *Sphenophyllum*, 1.

This flora contains several species identical with those in the Lower Carboniferous (Bernician) of Europe, corresponding to the mountain limestone. The agreement both in homotaxis and position is the more remarkable because of the startling contrast in the next stage. The only peculiarity is the presence of a *Glossopteris*. This comes from a different locality—Arowa—from most of the fossils, and the species is identical with one found in a much higher series. Under these circumstances it is impossible to feel satisfied that the specimen was really from this horizon. The evidence is not so clear as is desirable.

2. *Lower Coal-Measures with Marine Beds*.—The following plants are recorded:—

CYCADEACEÆ.—*Noeggerathiopsis*, 1 sp.
FILICES.—*Glossopteris*, 4.
EQUISETACEÆ.—*Annularia*, 1; *Phyllotheca*, 1.

In the marine beds, which are interstratified, are found lower Carboniferous (mountain limestone) marine fossils in abundance, such as *Orthoceras*, *Spirifer*, *Fenestella*, *Conularia*, &c. The plants belong to forms declared to be typically Jurassic by palæontologists. As the interstratification of the marine and plant-bearing beds has been repeatedly questioned by palæontologists, it is necessary to point out that the geological evidence brought forward by Mr. Clarke is of the clearest and most convincing character, that this evidence has been confirmed by all the geologists who are acquainted with the country, and has only been doubted by those who have never been near the place.

3. *Newcastle Beds*.—By all previous observers in the field these had been united to the preceding and the flora declared to be the same. Dr. Feistmantel has, however, pointed out important differences. Unfortunately, as he has been unable to examine the beds, it still remains uncertain whether the distinction, which has been overlooked by all the field geologists, is quite so great as it appears from the lists of fossils given. The following is the flora.—

CONIFERÆ.—*Brachyphyllum*, 1 sp.
CYCADEACEÆ.—*Zeugophyllites*, 1; *Noeggerathiopsis*, 3.
FILICES.—*Sphenopteris*, 4; *Glossopteris*, 8; *Gangamopteris*, 2; *Caulopteris* (?), 1.
EQUISETACEÆ.—*Phyllotheca*, 1; *Vertebraria*, 1.

The only animal known from the beds is a heterocercal ganoid fish, *Urosthenes australis*, a form with Upper Palæozoic affinities.

It will be noticed that the difference from the flora of the underlying beds associated with marine strata is chiefly specific, and by no means indicative of great difference of age, though the only species considered as common to the two by Dr. Feistmantel is *Glossopteris browniana*, found also in the Damuda series of India, in Tonquin, and in South Africa.

The plant fossils of the Newcastle beds and of the underlying series with marine fossils are those which exhibit so remarkable a similarity to the flora of the Indian lower Gondwánas, and especially to the Damudas. The same genera of plants, especially *Noeggerathiopsis*, *Glossopteris*, *Phyllotheca*, *Vertebraria* prevail in both. But the lower beds of Australia, to judge by the marine fauna, are of

Lower Carboniferous age, and it is impossible to suppose that the Newcastle beds are of very much later date. They are said to be conformable to the lower beds with marine fossils, and even to pass into them, and they should probably, if the lower beds are Lower Carboniferous, be classed as Middle or Upper Carboniferous. Thus if the evidence of marine faunas be accepted as decisive, the Damuda beds of India are homotaxially related to Jurassic strata in Europe and to Carboniferous in Australia.

But the Australian Newcastle flora has been quite as positively classed as Jurassic by European palæobotanists as that of the Damudas. It would be easy to quote a long list of authorities—McCoy, De Zigno, Saporta, Schimper, Carruthers, and others—in support of the Jurassic age of the Australian beds. For years the testimony of Australian geologists was rejected, and doubts thrown upon their observations. There is, so far as I know, no case in the whole history of palæontology in which the conflict of palæontological evidence has been so remarkably displayed.

4. *Hawkesbury Beds.*—The fauna and flora are poor. Only two fish, *Clithrolepis granulatus* and *Myriolepis clarkei*, and one plant, *Thinnfeldia odontopteroides*, are known, and of the three forms two recur in the Wianamatta beds.

An important character of the Hawkesbury beds, to which further reference will be made presently, is the occurrence of transported boulders,[1] apparently brought thither by the action of ice.

Similar boulders have been observed in certain sandstones in Victoria known as the Bacchus Marsh beds. From these beds two species of *Gangamopteris* have been described by McCoy. *Gangamopteris*, it should be recollected, is a genus of ferns closely allied to *Glossopteris* and abundant in the Damuda and still more so in the Karharbári beds of the lower Gondwánas in India.

5. *Wianamatta Beds.*—These are the highest portion of the whole system in New South Wales. They contain the following organic remains:—

ANIMALS.

PISCES.—*Palæoniscus antipodeus, Clithrolepis granulatus.*

PLANTS.

FILICES.—*Thinnfeldia (Pecopteris) odontopteroides, Odontopteris microphylla, Pecopteris tenuifolia, Tæniopteris wianamattæ.*
EQUISETACEÆ.—*Phyllotheca hookeri.*

The fish from the Wianamatta, Hawkesbury, and Newcastle beds, four in number, were considered as a whole by Sir P. Egerton to be most nearly allied to the Permian fauna of Europe.

The Wianamatta plants, like those in the lower beds, are classed as Jurassic.

6. *Higher Mesozoic Beds.*—These, which do not appear to have been traced into connection with the Wianamatta and Hawkesbury beds, occur in widely separated localities, from Queensland to Tasmania. The correlation of these widely scattered deposits, and the assignment of them collectively to a position above that of the

[1] Wilkinson, quoted by Feistmantel, *Rec. Geol. Surv. Ind.*, 1880, p. 250.

Wianamatta beds, appear solely founded upon the fossil flora, and it would be satisfactory to have in addition some geological evidence or some palæontological data derived from marine fossils. The Queensland flora is said to occur in beds overlying marine strata of Middle Jurassic age.

The following plants are recorded from these higher beds:—

CYCADEACEÆ.—*Zamites* (*Podozamites*), 3 sp.; *Otozamites*, 1.
FILICES.—*Sphenopteris*, 1; *Thinnfeldia*, 1; *Cyclopteris*, 1; *Alethopteris*, 1; *Tæniopteris*, 1; *Sagenopteris*. 1.
EQUISETACEÆ.—*Phyllotheca*, 1.

Tabulating, as in the case of the Indian Gondwána system, the age of the different Australian sub-divisions as determined by their fossil plants and animals on purely palæontological grounds, we have the following result:—

	Plants.	Animals.
6. Higher Mesozoic beds	Jurassic	Jurassic (marine).
5. Wianamatta beds.	Jurassic	Permian.
4. Hawkesbury beds	Jurassic	Permian.
3. Newcastle beds	Jurassic	Permian.
2. Lower Coal-Measures	Jurassic	Lower Carboniferous (marine).
1. Lower Carboniferous beds	Lower Carboniferous	......

South Africa.—In connection with the later Palæozoic and older Mesozoic rocks of Australia and India it is of importance to mention briefly the corresponding fresh-water or subaërial formations of Southern Africa, although in that country there are not such marked discrepancies in the palæontological evidence, perhaps because the relations of the beds with remains of animals to the plant-bearing strata are less clearly known. It will be sufficient to notice some of the most prominent peculiarities of these formations here, as I hope that a fuller account will be given to the section by Professor Rupert Jones, who has made an especial study of South African geology.

In the interior of South Africa, occupying an immense tract in the northern parts of Cape Colony, the Orange Free State, Transvaal, and the deserts to the westward of the last two, there is a great system of sandstones and shales with some coal-beds, generally known as the 'Karoo formation.' The sequence of sub-divisions is the following[1]:—

Stormberg beds, about 1,800 feet thick.
Beaufort „ „ 1,700 „ „
Koonap „ „ 1,500 „ „

The beds are but little disturbed in general, and form great plateaux. They rest partly on Palæozoic rocks (Carboniferous or Devonian), partly on gneissic forma-

[1] *Q. J. G. S.*, xxiii, 1867, p. 142.

tions. As in Australia, the underlying Palæozoic rocks contain a flora allied to the Carboniferous flora of Europe.

At the base of the Karoo formation are certain shales with coal, known as the Ecca beds, and remarkable for containing a great boulder-bed, the Ecca or Dwyka conglomerate,[1] like those in the Tálchir beds in India and the Hawkesbury sandstone in Australia, the boulders, precisely as in the Tálchir beds, being embedded in fine compact silt or sandstone, which in both countries has been mistaken for a volcanic rock.' The Ecca beds are said to contain *Glossopteris* and some other plants, but the accounts are as yet somewhat imperfect. The whole Karoo system, according to the latest accounts, rests unconformably on the Ecca beds, whilst the Ecca beds are conformable to the underlying Palæozoic strata.

Unfortunately, although a considerable number of animals and a few plants have been described from the 'Karoo formation,' it is but rarely that the precise sub-division from which the remains were brought has been clearly known.

The known species of plants are very few in number; *Glossopteris browniana,* and two other species of *Glossopteris,*[2] *Rubidgea,* a fern nearly akin to *Gangamopteris* and *Glossopteris,* and a *Phyllotheca*-like stem are recorded, without any certain horizon, but probably from the Beaufort beds. There is no doubt as to the close similarity of these plants to those from the Damudas of India and the Newcastle beds of Australia.

From the Stormberg beds there are reported *Pecopteris* or *Thinnfeldia odontopteroides, Cyclopteris cuneata,* and *Tæniopteris daintreei,*[3] three of the most characteristic fossils of the uppermost plant-beds in Australia, and all found in the Upper Jurassic Queensland beds.

The animals found in the Karoo beds[4] are more numerous by far than the plants. The greater portion have been procured from the Beaufort beds. They comprise numerous genera of dicynodont, theriodont, and dinosaurian reptiles, two or three genera of labyrinthodont amphibians, some fish allied to *Palæoniscus* and *Amblypterus,* and one mammal, *Tritylodon.* Of the above the *Tritylodon* and some reptilian and fish remains are said to be from the Stormberg beds.

Tritylodon is most nearly related to a Rhætic European mammal. The relations of the reptiles called *Theriodontia* by Sir R. Owen are not clearly defined, but representatives of them and of the *Dicynodontia* as already noticed are said to be found in the Permian of Russia. The *Glossopteris* and its associates may of course be classed as Carboniferous or Jurassic, according to taste. Neither the fauna nor flora show sufficiently close relations to those of any European beds for any safe conclusions as to age, even if homotaxis and synchronism be considered identical. On the other hand there are remarkable points of agreement with the faunas and floras of the Indian and Australian rocks.

Away from the typical Karoo area on the coast south of Natal there is found a series of beds, partly marine, sometimes called the Uitenhage[5] series. A few

[1] Sutherland, *Q. J. G. S.*, xxvi, p. 514.

[2] One classed by Tate as *Dictyopteris, Q. J. G. S.*, xxvii, p. 141.

[3] Dunn, 'Report on Stormberg Coal-Field,' *Geol. Mag.*, 1879, p. 552.

[4] Owen, 'Cat. Foss. Rept. S. Africa, Brit. Mus., 1876, &c.

[5] *Q. J. G. S.*, xxvii., p. 144.

cycads (*Otozamites*, *Podozamites*, *Pterophyllum*), a conifer, and ferns (*Pecopteris* or *Alethopteris*, *Sphenopteris*, *Cyclopteris*) are quoted from them, and three or four of the forms are closely allied or identical with species found in the Rájmahál beds of India.

It was at first supposed that the plant-bearing beds were lower in position than those containing marine fossils, and the whole of the Uitenhage series was considered as of later age than the Karoo beds. The marine beds were considered Middle Jurassic. Subsequently, however, Stow[1] showed conclusively that a portion of the marine beds, judging by their fossils, are of uppermost Jurassic or even Neocomian age, and also that the relation of the plant-bearing beds to the marine strata are far less simple than was supposed.[2] Indeed, to judge from Stow's account, it is by no means clear that a portion of the wood-bed series or saliferous series, to which the plant-beds belong, is not higher in position than the marine Jurassic strata.

There is a very extraordinary similarity between the geology of the southern part of Africa and that of the peninsula of India. In both countries a thick fresh-water formation, without any marine beds intercalated, occupies a large area of the interior of the country, whilst on the coast some marine Jurassic and cretaceous rocks are found, the former in association with beds containing plants. The coincidence is not even confined to sedimentary beds. As in India so in South Africa, the uppermost inland Mesozoic fresh-water beds are capped by volcanic rocks.

It has been assumed, but not apparently on any clear evidence, that the marine coast-beds and the associated plant-beds are in Africa much newer than the inland sandstone formation, but it is not impossible that the relations may really be the same as in India, and that the Stromberg beds of the inland formation may be the equivalents of the Upper Jurassic or even the cretaceous marine beds on the coast. The discovery of plants identical with those of the Jurassic (probably Upper Jurassic) beds of Queensland in the Stormberg series may of course be taken for what it is worth; it is of quite as much importance in indicating the age of the rocks as the occurrence of dicynodont reptiles in the Permian of Russia and in the lower Gondwánas of India.

Altogether there is quite sufficient probability that the upper Karoo or Stormberg beds are of later age than Triassic to justify the protest which I made last year against a skull being described from these beds as that of a 'Triassic' mammal.[3] The practice, so common amongst palæontologists, of positively asserting as a known fact the geological age of organisms from beds of which the geological position is not clearly determined, is very much to be deprecated.

I have called attention to the occurrence of boulders in the Tálchir beds in India, the Ecca beds of South Africa, and the Bacchus Marsh sandstones and Hawkesbury beds of Australia. The idea has occurred quite independently to several different observers that each of these remarkable formations affords evidence of glacial action; and although, in the case of India especially, the

[1] *Q. J. G. S*, xxvii., p. 479.

geographical position of the boulder-bed within the tropics seemed for a long time to render the notion of ice action too improbable to be accepted, further evidence has so far confirmed the view as to cause it to be generally received. Even before the Australian boulder-deposits had been observed it was suggested that the Tálchir beds and Ecca conglomerate might be contemporaneous;[1] and that the evidence in favour of a Glacial epoch having left its traces in the Permian beds of England[2] might possibly indicate that the Indian and South African boulder-beds are of the same geological epoch. The discovery of two similar deposits in Australia adds to the probability that all may have resulted from the same cause and may record contemporaneous phenomena. It would be very unwise to insist too much on the coincidence.

It would be easy to call attention to further examples of discrepancies in palæontological evidence, but I should weary you and nothing would be attained by going through instance after instance of deposits in distant parts of the world, the age of which has been solely determined by the examination of a few fossil forms of land and fresh-water animals and plants. I have, therefore, only taken a few with the details of which I have had occasion to become acquainted. In some of the most important cases I have mentioned, such as those of the Pikermi and Siwalik faunas, the Cutch (Umia beds) flora and that in the lower coal-measures of Australia, the conflict is between the evidence of the marine and terrestrial organisms. Manifestly one or the other of these leads to erroneous conclusions.

The general opinion of geologists is in favour of accepting the evidence of marine organisms. The reason is not far to seek. So far as I am aware, no case is known where such an anomaly as that displayed in the Gondwánas of India has been detected amongst marine formations of which the sequence was unquestioned. In the Gondwánas we have a Rhætic flora overlying a Jurassic flora, and a Triassic fauna above both. In Australia we find a Jurassic flora associated with a Carboniferous marine fauna, and overlaid by a Permian fresh-water fauna. The only similar case amongst marine strata is that of the well-known colonies of the late M. Barrande in Bohemia, and in this instance the intercalation of strata containing later forms amongst beds with older types is disputed, whilst the difference in age between the faunas represented is not to be compared to that between Triassic and Jurassic.

There is, however, another and an even stronger reason for accepting the evidence of marine instead of that afforded by terrestrial and fresh-water animals and plants. If we compare the distribution of the two at the present day we shall find a very striking difference, and it is possible that this difference may afford a clue to the conditions that prevailed in past times.

Wanderers into what they fancy unexplored tracts in palæontology are very likely to find Professor Huxley's footprints on the path they are following. I have had occasion to turn to a paper of his on '*Hyperodapedon*,'[3] that very curious reptile

[1] *Q. J. G. S.*, xxxi., p. 528.
[2] *Q. J. G. S.*, xi., p. 185.
[3] *Q. J. G. S.*, xxv., p. 150.

already mentioned, of which the remains occur both in Great Britain and in India, and I find the following remarks, which appear so exactly to express a portion of the view to which I wish to call your attention, that I trust I may be excused for quoting them. Professor Huxley writes:—

'It does not appear to me that there is any necessary relation between the fauna of a given land and that of the seas of its shores. The land-faunæ of Britain and Japan are wonderfully similar; their marine faunæ are in several ways different. Identical marine shells are collected on the Mozambique coast and in the easternmost islands of the Pacific; whilst the faunæ of the lands which lie within the same range of longitude are extraordinarily different. What now happens geographically to provinces in space is good evidence as to what, in former times, may have happened to provinces in time; and an essentially identical land-fauna may have been contemporary with several successive marine faunæ.

'At present our knowledge of the terrestrial faunæ of past epochs is so slight that no practical difficulty arises from using, as we do, sea-reckoning for land-time. But I think it highly probable that sooner or later the inhabitants of the land will be found to have a history of their own.'

When these words were written more than fifteen years ago very few of the geological details to which I have called your attention were known. I need not point out how wonderful a commentary such details have afforded to Professor Huxley's views.

I have no desire to quote authority. I fear that in the facts I have been laying before you my quotations of the most authoritative writers have been made less for the purpose of showing reverence than of expressing scepticism. My reason for calling attention to Professor Huxley's views is different. I entirely agree with them; but there is, I think, something to be added to them. There is, I believe, an additional distinction between land and marine faunas that requires notice, and this distinction is one of very great importance and interest. It appears to me that at the present day the difference between the land-faunas of different parts of the world is so vastly greater than that between the marine faunas that if both were found fossilised, whilst there would be but little difficulty in recognising different marine deposits as of like age from their organic remains, terrestrial and fresh-water beds would in all probability be referred to widely differing epochs, and that some would be more probably classed with those of a past period than with others of the present time.

I had proposed to enter at some length into this subject, and to attempt a sketch of the present state of our knowledge concerning the distribution of terrestrial and marine faunas and floras. But I found that it was impossible to do justice to the question without making this address far longer than is desirable, and I have already taken up more time than I ought to have done. I can therefore only treat the subject very briefly.

As you are doubtless aware, the most important work upon the distribution of terrestrial animals yet published is that of Mr. Wallace. He[1] divides the earth's

[1] Dr. P. L. Sclater was the original author of the sub-division adopted by Mr. Wallace.

surface into six regions—Palæarctic, Ethiopian, Oriental, Australian, Neotropical, and Nearctic. Some naturalists, with whom I am disposed to agree, consider Madagascar and the adjacent islands a seventh region, and it is possible that one or two other additions might be made.

These regions are essentially founded on the distribution of *vertebrata*, especially mammals and birds, and the following table, taken from Wallace's lists, shows the percentage of peculiar families of vertebrata and peculiar genera of mammalia in each region, mammalia being selected as being more characteristic than birds and better known than reptiles, amphibians, or fishes :—

REGIONS.	Total families of Vertebrates.	Peculiar Families.	Percentage of Peculiar Families.	Total Genera of Mammals.	Peculiar Genera of Mammals.	Percentage of Peculiar Genera.
Palæarctic	137	3	2·2	100	37	37
Ethiopian	175	23	13·1	142	90	63
Oriental	163	12	7·4	118	54	46
Australian	142	30	21 1	70	45	65
Neotropical	168	45	26·8	131	103	79
Nearctic	121	12	9·9	74	24	C2

The marine mammals and reptiles are too few in number to be compared with the land-fauna, but whales, porpoises, seals, sirenians, turtles and sea-snakes are for the most part widely diffused. The best class of the vertebrata for comparison is that of the fishes, and some details taken by Wallace from Günther's 'British Museum Catalogue' are very important. The whole class is divided into 116 families, of which 29 are exclusively confined to fresh water, whilst 80 are typically marine. Of these 80 no less than 50 are universally, or almost universally, distributed, whilst many others have a very wide range. Four families are confined to the Atlantic and 13 to the Pacific Ocean, whilst a few more are exclusively southern or northern. About 63 are found in both the Atlantic and Pacific.

Now, of the 29 fresh-water families, 15, or more than one-half, are confined each to a single region, 9 are found each in two regions, 2 in three regions, and the same number in four; one only (*Cyprinidæ*) is found in five regions, whilst not one is met with in all six. It is impossible to conceive a greater contrast: 50 marine families, or 62·5 per cent., have a world-wide distribution, whilst not a single fresh-water family has an equally extended range, and more than one-half are confined each to a single region.

The regions adopted by Wallace, as already stated, are founded on the *vertebrata;* he considers, however, that the distribution of the invertebrates is similar. So far as the terrestrial mollusca are concerned, I am inclined to dissent from this view. But for one circumstance the mollusca would afford an admirable test of the theory that marine types—species, genera, and families—are much more widely spread than terrestrial. I am assured that this is the case, but the

difficulty of proving it arises from the fact that the classification of pulmonate terrestrial mollusca, as adopted by naturalists generally, is so artificial as to be worthless. Genera like *Helix*, *Bulimus*, *Achatina*, *Pupa*, *Vitrina*, as usually adopted, are not real genera, but associations of species united by characters of no systematic importance, and the attempts that have hitherto been made at a natural classification have chiefly been founded on the shells, the animals not being sufficiently known for their affinities, in a very large number of cases, to be accurately determined. Of late years, however, more attention has been devoted to the soft parts of land mollusks, and in Dr. Paul Fischer's 'Manuel de Conchyliologie' now being published, a classification of the Pulmonate Gasteropoda is given, which, although still imperfect for want of additional information, is a great improvement upon any previously available. In this work the first 13 families of the *Pulmonata Geophila* comprise all the non-operculate land mollusca, or snails and slugs, and these 13 families contain 82 genera thus distributed:—

Peculiar to one of Wallace's land regions	54
Found in more than one, but not in both America and the Eastern hemisphere	12
Common to both hemispheres	16

The last 16, however, include *Limax*, *Vitrina*, *Helix*, *Pupa*, *Vertigo*, and some other genera which certainly need further repartition. The operculated land-shells belonging to a distinct sub-order, or order, and closely allied to the ordinary prosobranchiate gasteropoda, are better classified, the shells in their case affording good characters. They comprise four well-marked families (*Helicinidæ*, *Cyclostomidæ*, *Cyclophoridæ*, and *Diplommatinidæ*), besides others less well marked or but doubtfully terrestrial. Not one of the families named is generally distributed, and the genera are for the most part restricted to one or two regions. The portion of Dr. Fischer's manual relating to these mollusca is unpublished, and the latest general account available is that of Pfeiffer, published in 1876.[1] From this monograph I take the following details of distribution. The number of genera enumerated is 64 (including *Proserpinidæ*).

Peculiar to one of Wallace's land regions	48
Found in more than one, but not in both America and the Eastern hemisphere	8
Common to both hemispheres	8

It is the distribution of the terrestrial operculate mollusca which induces me to suspect that the distribution of land mollusca differs from that of land vertebrates. One instance I may give. There is nowhere a better marked limit to two vertebrate faunas than that known as Wallace's line separating the Australian and Oriental regions, and running through the Malay archipelago between Java, Sumatra, and Borneo, on the one hand, and Papua with the neighbouring groups on the other. There is in the two regions a very great difference in the vertebrate genera, and a considerable replacement of families. The Oriental *vertebrata* contain far more genera and families common to Africa than to Australia. Now, the operculate land-shells known from New Guinea and Northern Australia

[1] *Monographia Pnemonopomorum Viventium Supp.* iii.

belong to such genera as *Cyclophorus*, *Cyclotus*, *Leptopoma*, *Pupinella*, *Pupina*, *Diplommatina*, and *Helicina*, all found in the Oriental region, and mostly characteristic of it, whilst the only peculiar types known are *Leucoptychia*, closely allied to *Leptopoma*, from New Guinea, and *Heterocyclus*, apparently related to the Indian *Cyathopoma*, from New Caledonia. Farther east in Polynesia there are some very remarkable and peculiar types of land-shells, such as *Achatinella*, but these do not extend to Australia or Papua. On the other hand, scarcely a single Oriental genus extends to Africa, the terrestrial molluscan fauna of which continent differs far more from that of the Oriental region than the latter does from that of tropical Australia.

The same is the case with plants. In an important work lately published by Dr. O. Drude, of Dresden, the tropics of the Old World are divided into three distinct regions—(1) tropical Africa; (2) the East African Islands, Madagascar, &c.; (3) India, South-Eastern Asia, the Malay archipelago, Northern Australia, and Polynesia.

A very large proportion of the families and even of the genera of marine mollusca are almost of world-wide distribution, and even of the tropical and sub-tropical genera the majority are found in all the warmer seas. I have no recent details for the whole of the marine mollusca, but a very fair comparison with the data already given for land-shells may be obtained from the first 25 families of Prosobranchiate Gasteropoda, all that are hitherto published in Fischer's manual. These 25 families include *Conidæ*, *Olividæ*, *Volutidæ*, *Buccinidæ*, *Muricidæ*, *Cypreidæ*, *Strombidæ*, *Cerithiidæ*, *Planaxidæ* and their allies, and contain 116 living marine genera, the known range of which is the following:—

Found only in the Atlantic Ocean	15	
Found only in the Pacific or Indian Ocean, or both	28	
Found only in Arctic or Antarctic Seas, or in both	12	
		— 55
Found in the warmer parts of all oceans	34	
Widely, and for the most part universally, distributed	27	
		— 61

That is, 52·6 per cent. are found in both hemispheres, whilst only 19·5 per cent. of the inoperculate, and 12·5 per cent. of the operculate land mollusca, have a similar distribution. This is, however, only an imperfect test of the difference, which is really much greater than these numbers named imply by themselves.

Some genera of fresh-water mollusca, as *Unio*, *Anodon*, *Cyclas*, *Lymnea*, *Planorbis*, *Paludina*, and *Bythinia*, are very widely spread, but a much larger number are restricted. Thus if *Unio* and *Anodon* are extensively distributed, all allied fresh-water genera, like *Monocondylæa*, *Mycetopus*, *Iridina*, *Spatha*, *Castalia*, *Ætheria*, and *Mülleria* inhabit one or two regions at the most. The same result is not found from taking an equally important group of marine mollusca, such as *Veneridæ* or *Cardiadæ*.

Throughout the marine invertebrata, so far as I know, the same rule holds good: a few generic types are restricted to particular seas; the majority are found in suitable habitats throughout a large portion of the globe. The marine provinces that have been hitherto distinguished, as may be seen by referring to

those in Woodward's 'Manual of the Mollusca,' or Forbes and Godwin Austen's 'Natural History of the European Seas,' or 'Fischer's 'Manuel de Conchyliologie,' or Agassiz's 'Revision of the Echini,' are founded on specific distinctions, whilst the terrestrial regions are based on generic differences, and often on the presence or absence of even larger groups than genera.

Botany offers a still more remarkable example. I have just referred to Dr. Oscar Drude's work,[1] published within the last few months, on the distribution of plants. Dr. Drude divides the surface of the globe into four groups of floral regions (*Florenreichsgruppe*), and these again into floral regions (*Florenreiche*), fifteen in number, which are again divided into sub-regions (*Gebiete*). The first group of floral regions is the oceanic, comprising all the marine vegetation of the world; and so uniform is this throughout that no separate regions can be established, so that there is but one oceanic to contrast with fourteen terrestrial regions.

It is impossible to enter further into this subject now, and I can only allude to the evidence in favour of the existence of land-regions in past times. It is scarcely necessary to remind you of the proofs already accumulated of differences between the fauna of distant countries in Tertiary times. The Eocene, Miocene, and Pliocene vertebrata of North America differ quite as much from those of Europe in the same periods as do the genera of the present day; and there was as much distinction between the mammalia of the Himalayas and of Greece when the Siwalik and Pikermi faunas were living as there is now. In Mesozoic times we have similar evidence. The reptiles of the American Jurassic deposits present wide differences from those of the European beds of that age, and the South African reptilian types of the Karoo beds are barely represented elsewhere. But there is no reason for supposing that the limits or relations of the zoological and botanical regions in past times were the same as they now are. It is quite certain indeed that the distribution of land-areas, whether the great oceanic tract has remained unchanged in its general outlines or not, has undergone enormous variations, and the migration of the terrestrial fauna and flora must have been dependent upon the presence or absence of land communication between different continental tracts; in other words, the terrestrial regions of past epochs, although just as clearly marked as those of the present day, were very differently distributed. The remarkable resemblance of the floras in the Karoo beds of South Africa, the Damuda of India, and the coal-measures of Australia, and the wide difference of all from any European fossil flora, is a good example of the former distribution of life; whilst it is scarcely necessary to observe that the present Neotropical and Australian mammals resemble those of the same countries in the later Tertiary times much more than they do the living mammalia of other regions, and that the Australian mammal fauna is in all probability more nearly allied to the forms of life inhabiting Europe in the Mesozoic era than to any European types of later date. If the existing mammals of Australia had all become extinct, a deposit containing their bones would probably have been classed as Mesozoic.

The belief in the former universality of faunas and floras is very much connected with the idea once generally prevalent, and still far from obsolete, that the temperature of the earth's surface was formerly uniform, and that at all events

[1] Petermann's *Mittheilungen*, Ergänzungsheft, No 74, 'Die Florenreiche der Erde.'

until early or even middle Tertiary times the poles were as warm as the equator, and both enjoyed a constant tropical climate. The want of glacial evidence from past times in Spitzbergen and Greenland, where a temperature capable of supporting arboreal vegetation has certainly prevailed during several geological periods, is counterbalanced by the gradually accumulating proofs of Lower Mesozoic or Upper Palæozoic glacial epochs in South Africa, Australia, and strangest of all in India. Even during those periods of the earth's history when there is reason to believe that the temperature in high latitudes was higher than it now is, evidence of distinct zones of climate has been observed, and quite recently Dr. Neumayr,[1] of Vienna, has shown that the distribution of Cretaceous and Jurassic *cephalopoda* throughout the earth's surface proves that during those periods the warmer and cooler zones of the world existed in the same manner as at present, and that they affected the distribution of marine life as they do now.

The idea that marine and terrestrial faunas and floras were similar throughout the world's surface in past times is so ingrained in palæontological science that it will require many years yet before the fallacy of the assumption is generally admitted. No circumstance has contributed more widely to the belief than the supposed universal diffusion of the Carboniferous flora. The evidence that the plants which prevailed in the coal-measures of Europe were replaced by totally different forms in Australia, despite the closest similarity in the marine inhabitants of the two areas at the period, will probably go far to give the death-blow to an hypothesis that rests upon no solid ground of observation. In a vast number of instances it has been assumed that similarity between fossil terrestrial faunas and floras proves identity of geological age, and, by arguing in a vicious circle, the occurrence of similar types assumed without sufficient proof to belong to the same geological period has been alleged as evidence of the existence of similar forms in distant countries at the same time.

In the preceding remarks it may perhaps have surprised some of my auditory that I have scarcely alluded to any American formations, and especially that I have not mentioned so well-known and interesting a case of conflicting palæontological evidence as that of the Laramie group. My reason is simply that there are probably many here who are personally acquainted with the geology of the American Cretaceous and Tertiary beds, and who are far better able to judge than I am of the evidence as a whole. To all who are studying such questions in America I think it will be more useful to give the details of similar geological puzzles from the Eastern hemisphere than to attempt an imperfect analysis of difficult problems in the great Western continent.

Perhaps it may be useful, considering the length to which this address has extended, to recapitulate the principal facts I have endeavoured to bring before you. These are—

1. That the geological age assigned on homotaxial grounds to the Pikermi and Siwalik mammalian faunas is inconsistent with the evidence afforded by the associated marine deposits.

[1] 'Ueber klimatische Zonen während der Jura und Kreidezeit,' *Denkschr. Math. Nat. Cl. Akad. Wiss. Wien*, vol. xlvii. 1883.

2. The age similarly assigned on the same data to the different series of the Gondwána system of India is a mass of contradictions; beds with a Triassic fauna overlying others with Rhætic or Jurassic floras.

3. The geological position assigned on similar evidence to certain Australian beds is equally contradictory, a Jurassic flora being of the same age as a Carboniferous marine fauna.

4. The same is probably the case with the terrestrial and fresh-water faunas and floras of South Africa.

5. In instances of conflicting evidence between terrestrial or fresh-water faunas and floras on one side, and marine faunas on the other, the geological age indicated by the latter is probably correct, because the contradictions which prevail between the evidence afforded by successive terrestrial and fresh-water beds are unknown in marine deposits, because the succession of terrestrial animals and plants in time has been different from the succession of marine life, and because in all past times the differences between the faunas and floras of distant lands have probably been, as they now are, vastly greater than the differences between the animals and plants inhabiting the different seas and oceans.

6. The geological age attributed to fossil terrestrial faunas and floras in distant countries on account of the relations of such faunas and floras to those found in European beds has proved erroneous in so large a number of cases that no similar determinations should be accepted unless accompanied by evidence from marine beds. It is probable in many cases—perhaps in the majority—where the age of beds has been determined solely by the comparison of land or fresh-water animals or plants with those found in distant parts of the globe, that such determinations are incorrect.

Afghan Field-notes by C. L. GRIESBACH, F.G.S., *Geological Survey of India (on duty with the Afghan Boundary Commission).*

Route.

The march of the Afghan Boundary Commission was first from Quetta to Nushki, after crossing the Lora south of the Pishin valley; from Nushki to Khwaja Ali on the Helmund (east of Rudbar) by long and weary marches. We followed the river down to Chahar Burjak, where we crossed it. From this point we went in a more or less northward direction through Kalah-i-Fath past the Helmund Lakes to Lash-Juwain, through the Anardara pass, and passing Sabzawár westwards, to Pahri and eventually to Kuhsán on the Hari Rud, avoiding Herat altogether. Here General Sir Peter Lumsden, K.C.B., joined our party under Colonel Ridgeway.

On the 25th November, the General with a small party left us to go *viâ* Chasm-Sabz (not on the old maps) and Panjdeh to these our winter quarters on the Murgháb river. We followed next day by another route to Kushk, finally all meeting at Bála Murgháb. At Kushk, I obtained permission to go off by myself on a geological trip; I returned to the Herat valley by the Band-i-Bábá, went to within a mile of Herat city, afterwards returning over the Band-i-Zurmust to Kila Náu and to Bála Murgháb.

River drainage.

The march from India to the valley of the Murgháb has taken us from Eastern Biluchistan, which belongs to the Indus drainage into the Lora and Helmund basins (Seistan, &c.) and thence over the great watershed south of Herat, into the Central Asian basin of the Hari Rud and the Murgháb. The watershed which divides Southern Afghanistan from Central Asia, is formed as far as we know by the range of mountains called on our maps the Siah Koh, with its western continuation, the Doshakh mountains.

There seems to exist a marked difference in the geological features of the areas divided by this great range, and I intend therefore to treat them separately in these notes.

The time was too limited to admit of a regular geological survey of the country traversed, but I believe the notes collected with the experience gained in my former work in Afghanistan has enabled me to come to fairly accurate conclusions with regard to the geology of the country.

Southern Afghanistan and Biluch desert.

As will even be clear from a view of the old map of Afghanistan[1] the country lying between Nushki and the Helmund, with much of the area to the north of it, is nothing but a desert now, though water may be found in most localities by digging wells.

The features of the whole area are similar to those described between Kandahar and Quetta, consisting of more or less parallel ranges, which run between east—west and north-east—south-west, separated by wide stretches of dasht-deposits, which reach an enormous thickness in the Lower Helmund valley.

The ranges which we crossed in succession south of the Helmund are merely continuations of ranges which I have described already in my memoir on Southern Afghanistan, and I may at once say that, with the exception of one or two points, I could not elucidate any new fact in relation to the rocks which compose the hill ranges *south* of the Doshakh range south-west of Herat; north of these hills the character of the rocks entirely changes.

Ghaziaband range.

Between Quetta and Nushki, I crossed the "Ghaziaband" range at a point south-west of my old route of 1880, and near the village of Karnak. I wish I could have remained a few days in that neighbourhood; there are several points of geology connected with the section of this range which are not at all clear to me. The country is now, however, quite accessible to any one, and will no doubt before long be carefully surveyed.

Siwaliks of Biluchistan.

The range is skirted on its south-east slope by clays, of red and greenish white colour, which re-appear in considerable thickness in the Lora basin. In 1880, I believed them to represent the Gáj beds of Sind, which Mr. Blanford disputes, and I believe on good grounds. Since then I have had an opportunity of seeing the Siwalik rocks of the Deraját, Kohát district and the Trans-Indus Salt-range. There, especially in the latter area, a great thickness of red and greenish-white clays, sandstones and conglomerates overlie the cretaceous beds, and are considered by Wynne to be representatives of the Lower Siwaliks. I was struck with the lithological likeness of these Trans-Indus Siwalik beds with what I remembered the Ghaziaband beds to be

[1] General Walker's map, 1 inch = 32 mile, 1883.

I have had now a second opportunity of visiting the latter, and the resemblance of them to the Salt-range Siwaliks seems to me perfect. If my supposition is correct, then these beds do not represent Upper but the Lower Siwalik beds. Fossils I have none out of them.

Eocene sandstones of Karnak.

The greenish-grey sandstone and shales which compose the pass leading from Karnak to Panjpai, may be the same as the nummulitic sandstone (Flysch ?), which I saw in 1880 in the Ghaziaband pass; but if so, their character changes slightly towards the south-west. I believe the Karnak beds resemble rather the Khojak group of rocks.

Khojak beds.

Between Panjpai and Nushki one crosses the hill ranges which form the south-western spurs of the Khojak Amran mountains, and, as I expected, the geological structure of the hills is the same; the principal rocks are sandstones and hard splintery shales, all much contorted, of exactly the same lithological character as the Khojak beds. Near Kaisar, east of Nushki, I met traps and a granitic rock of similar characters to those of the trap and granitic rocks of Gatai and Dobrai, north of the Khojak.

When I first crossed the latter pass in 1880, it seemed to me probable that the hippuritic limestones, which compose the isolated hills on the north-west side of the Khojak Amran range, dipped below the Khojak sandstone; I therefore believed the latter to belong to the upper cretaceous series, equivalent perhaps to the "Vienna Sandstone" of the northern Alps. Since then I have had an opportunity of actually crossing the Sulemán range,[1] and I found there a formation of sandstone and shales underlying the upper cretaceous beds of the Takht-i-Sulemán, which appear to me to be of the same lithological character as the Khojak beds. If they represent these beds, then the latter would probably belong to the lower cretaceous series rather than the upper, and my interpretation of the broken section of the Khojak would be erroneous. A careful study of the hills between Panjpai and Nushki will, no doubt, settle this point.

Post-tertiaries of Biluchistan.

The valleys between the rugged hill ranges of this part of Biluchistan are partly filled by post-tertiary and recent deposits, mostly gravels and clays, with a capping of a widely spread bed of conglomerate and breccia, which I also found forming extensive plains in Southern Afghanistan.

Aerial formations.

Aerial formations in the shape of blown sand cover large tracts in these wide valleys, and practically all the level country between Nushki and the Helmund is covered with sand-hills. It is characteristic of them that they generally form low hills of crescent shape, with the horns and the scarp turned to leeward; the inclined plane formed by the currents of air are therefore generally dipping westwards and show a rippled surface, resembling closely the accumulations of drift snow on the high Himalayas.

As the sand-hills gradually advance, they uncover here and there the beds below, which are generally a thin plastering of clays on the top of the conglomerate already noticed.[2]

[1] *Supra*, Vol. XVII, part 4.

[2] Memoirs, Geol. Surv. Ind., XVIII, p. 14.

Igneous rocks, of the Biluch desert.

The higher hills between Nushki and Galichah are all formed of igneous rocks, most of them of a basic type. At a few points isolated masses of a granitic rock appear, and near Galichah (Malik Dokan) I met a calcareous contact rock with veins of gypsum and a serpentine with veins of chrysolite, which is quarried by the natives for ornamental purposes.

At Galichah one enters the Lut, a great desert which stretches down to the Helmund river, and the greater part of which is covered with blown sand.

The Helmund basin.

The geological features of the western part of the Helmund area are extremely simple. All the higher ranges are the western and south-western continuations of offshoots from the Siah-Koh, and are composed of upper cretaceous beds (hippuritic limestone) with associated traps and syenitic granite. The limestone is fossiliferous throughout: hippurites are found in great numbers in all beds of this formation. Near the igneous rocks the limestone is converted into a fine-grained white marble.

Hippuritic limestone. Igneous rocks.

Contact rock.

The contact rock between the hippuritic limestone and the trap is precisely of the same character as the rock which contains the gold near Kandahar, and is found in a similar position. It is *in situ* north of Sher Buksh.

Syenitic granite.

The range north of Kala-i-Kah and the greater mass of the hills crossed between this point and Pahri are formed of hippuritic limestone with intrusions of trap. The valley of the Karez-i-Dasht, north of the Anardara pass, is formed of syenitic granite, of later age and intrusive in the trap.

Tertiaries of South Afghanistan, near Pahri.

Red and white clays, very like the beds of the Ghaziaband pass, near Quetta, form some of the lower ranges and plateaux between the trap hills of Sher Buksh and Pahri. Near the latter place the beds of this formation are raised up and dip north-west at a varying angle. Near Chah Gazek I found some remains of mammalian bones in a bad state of preservation. Perhaps these beds are of Siwalik age. They are certainly older than the clays, sandstones, and conglomerates which overlie them, and which further south form widespread areas in the lower Helmund basin.

Mammalian bones.

Afghan Seistan. Newer tertiaries and recent rocks.

The geological features of Afghan Seistan are extremely simple. Only later tertiary and recent deposits are met with. The former are of fluviatile and aerial origin, and overlie the coloured clays with mammalian remains of Chah Gazek.

The prevailing rocks are clays, soft sandstones, and gravels, locally with enormous thicknesses of "loess" beds. The latter are thick unstratified beds of fine silt, with false-bedded sandy layers. Veins of gypsum are frequent, and cavities, occasionally still retaining some lignitic rootlets and stems of plants, are found throughout the deposit; such cavities are also characteristic of the "loess" deposits of Europe, which are now generally supposed to be of aerial origin.

These beds form high scarps along the banks of the Helmund, and lower down along the eastern shores of the Hamún, where they are well exposed. In litholo-

gical character they resemble the Upper Manchhars of the Nari gorge, near Sibi, of which they are probably an equivalent.

Post-tertiaries and recent.

Recent and post-tertiary deposits, soft sandstones and conglomerates, both containing worn material from the neighbouring hill ranges, are found in considerable thickness in the Farah Rud, the Kash Rudak, and capping the mammalian beds of Seistan and Biluchistan. Locally the conglomerate is replaced by a hard limestone breccia (near Galichah in Biluchistan), but the group of rocks is everywhere seen to overlap and even to rest quite unconformably on the underlying mammal beds of Seistan. They resemble in general character the post-tertiaries of Sind, of the Deraját, and the Punjab. In general outlines the drainage which produced these beds must have been identical with the drainage of the rivers of the present day, though here and there the area may have been much more extended.

The great watershed of Central Asia.

The range which runs more or less with the 34° North latitude, and which on our maps bears the names of the Siah Koh and Doshakh mountains, marks a complete change in the geological structure of Central Asia. Whereas south of this range no older rocks than of the cretaceous period are known to exist, the Doshakh range itself consists of palæozoic rocks, and between them and the Tir-band-i-Turkistan range is a series of beds all dipping more or less north or north-east, and comprising the entire upper palæozoic and mesozoic series.

Sections obtained.

Up to the present I obtained the following sections. In the Doshakh range, from Pahri to Zindaján (Herat valley); over the Chillingak pass, east of the Doshakh peaks, and from Zindaján to Robat-i-pai; in the Paropamisus, the Band[1]-i-Kaitu, the Band-i-Bába and the Band-i-Zurmust. Unfortunately these sections require connecting before I can form a perfectly clear idea about the structure of these mountain ranges, but I believe that I shall have another opportunity of crossing the Herat valley before leaving Afghanistan, to complete my work. I found the following groups of rocks in the area between the Doshakh range and the Tir-band-i-Turkistan:—

List of formations.

In descending order:—

Recent and post-tertiary	Alluvium of Hari Rud and Murgháb sandstone and conglomerates.
Siwaliks, Upper	Sandstones, grits, clays of Ghorian and Tirpul (Hari Rud).
" Lower	Red and white clays of Chesm Sabz, Sakhra (Murgháb).
Cretaceous	Tir-band-i-Turkestan beds.
Jurassic	Kushk sandstones, Chakán beds.
Trias and Rhaetic	Plant-beds of Band-i-Bába, Zurmust and Naratú.
Permian ?	Talchir conglomerates, sandstones, and shales. Trap.
Carboniferous	Productus beds of Robat-i-pai.

In describing the rocks I will begin with the oldest formation, which was also the first noticed on entering the Central Asian region.

[1] Band = pass.

The Doshakh range appears to be formed of one or more great anticlinals. The south side of the range is composed of hippuritic limestone, but unfortunately I had no opportunity of finding out the relations of the cretaceous beds to the older rocks composing the main range. From what I could learn by crossing the Chillingak pass from Pahri to Zindaján, and from a section made from the latter place to Robat-i-pai (near the centre of the Doshakh hills), it appears that a grey sandstone with friable shales, somewhat resembling in its lithological character the Khojak beds, is overlaid by hard dark-blue limestone with calcspar veins which contains carboniferous fossils in great abundance. There are several species of *Producti*, amongst them *Pr. semi-reticulatus*, *Athyris roissyi*, *Fenestella*, and corals.

Carboniferous.

These limestones dip about 20° north to north-east below the alluvial deposits of the Hari Rud. Immediately north of Robat-i-pai, on the north side of the Hari Rud valley, all the older beds are hidden by extensive clay and sandstone beds of late tertiary age.

A section through the Paropamisus *viâ* the Ardewan pass (north of Herat) may probably reveal a continuous section, and this I hope to accomplish as soon as the weather becomes more favourable.

The section over the Band-i-Bába from Kushk to Herat is incomplete, as the route which I had to follow over the pass more often than not runs in the direction of the strike of beds and over the debris and recent deposits on the south slope of the range.

Band-i-Bába section.

I found north-east of Herat the low spurs which reach to within 1,500 yards of the city, and on which the Ziarat Khwaja Abdullah-i-Ansari at Ghazegah is built, to consist of a grey thinly bedded gneiss with granitic veins, dip north-east. The overlying beds I did not see, nor could I find again the carboniferous Productus limestone in the Band-i-Bába section. The part of the Paropamisus intervening between this point and the south side of the Band-i-Bába pass near Palezkár I could not touch anywhere, but from the debris found on the great "fans" south of it, I should say that carboniferous beds will be found north of Herat. The Band-i-Bába is greatly contorted, and the centre range itself is formed by a great anticlinal, which is followed towards the east and south-east by a succession of folds, which probably are continued to the Davendár range.

Hills near Herat, gneiss.

At the south side of Bába pass near Palezkár I found an extensive formation, all the beds of which dip to the east and south-east, seemingly quite unconformably to the gneiss of Ghazegah and the main range; I recognised it at once and without trouble as Talchir, the basal group of the Indian Gondwána system. Boulder beds, conglomerates, greenish sandstones, and shales predominate, accompanied by red and yellow clays and interbedded trap. The latter is a feature which reminded me at once of the boulder-bed of the Karoo formation of South Africa. Both the sandstone and the shales contain traces of plants, belonging to Vertebraria apparently.

Talchirs near Palezkár.

Whether these plant-beds rest unconformably on the carboniferous limestones, as the differing dip and strike would indicate, I am at present unable to

say, but hope to settle this point before very long. I could not go east of Kurukh to the Davendar range, where probably the upper beds of the Gondwánas would be met with.

Upper plant-beds of the Bába pass.

In the Bába pass the Talchirs seem to form the lowest beds of the anticlinal and are overlaid by a great thickness of sandstones, limestones, and shales, which form the top of the pass and the long sloping plateau of the north limb of the anticlinal as far as Chakán and Kushk. These beds I believe to represent the entire middle and upper Gondwána series. Plant-beds alternate with great thickness of grits and sandstones, and a few partings of Ostrea beds (limestones) are found towards the upper half of the group.

Sandstones of Band-i-Kaitú.

The sandstones and grits assume an enormous development towards the western portion of the Paropamisus; the Band-i-Kaitú is entirely composed of sandstones, grits, and conglomerates of the character of the Mahadeva sandstone.

Band-i-Zurmust.

Coral limestone.

The Band-i-Zurmust shows a similar geological structure with one difference. Within the group of Talchirs, and towards the lower half of it, appears a grey limestone, containing coral remains and a Nautilus. Plant-beds overlie this limestone, and the north slope of the Zurmust with the Naratú hill seems to be composed of plant-beds of middle Gondwána character. The upper strata of this series between Naratú and Chakán seem to have fewer plant-beds, whereas the Ostrea limestones increase in thickness.

Coast formation.

This group of rocks presents all the appearance of having been deposited along and near a sea-coast line; especially the upper portion of it north of the Zurmust must have been formed along a low sea coast probably of varying outlines, and we thus have beds presenting all the character of our Gondwánas with plants, the strata showing false bedding, alternating in the higher horizons with marine shell limestones.

Shell limestone of Kila Naú. Jurassic.

The plant beds are followed by thick strata of an earthy-white limestone of chalky texture, full of the casts of gasteropods and bivalves, alternating with a white calcareous sandstone with numerous bivalves. These beds form a belt north of the Paropamisus, and are well seen between Kushk and Kila Naú, wherever the affluents of the Kushk and Murgháb rivers form deep ravines in the plateaux.

Tir-band-i-Turkistan. Cretaceous fossils.

I believe this white shell limestone series belongs to the upper jurassic epoch; it is overlaid by the Tir-band-i-Turkistan limestones, amongst which I certainly found beds with cretaceous fossils, but the description of which I reserve for my next note.

Tertiaries: Siwaliks.

Red and greenish-white clays are in great force in the wide-stretching high plain of Chesm Sabz, north-east of Kuhsan, and are overlaid near Tirpul, in the Hari Rud valley, by sandstones, silts, clays, and grits. I believe that this series represents the Siwaliks. Similar beds, with great deposits of gypsum, and containing some

fossils, casts of shells of Unio, and the casts of Annelids, I met near Sakhra on the Murgháb.

BALA MURGHÁB;

8th January 1885.

CORRIGENDUM.

The Phosphatic rocks *at* Musuri (Mussooree) (*supra*, Vol. XVII, p. 198).

In the determination of the composition of the phosphatic minerals sent by the Rev. Mr. Parsons from Mussooree, as given in the last number of the Records, two operators were implicated, and owing to the absence on leave of Mr. Mallet and myself it was not known that one of them, our new Museum Assistant, was very inexperienced in laboratory work. Mr. Mallet had taught him how to make the ordinary assay of a limestone, but of general chemical analysis he knew next to nothing. It thus befell that when heunder took to determine the lime in these stones, not knowing the peculiar behaviour of this substance in the presence of phosphoric acid, he only obtained the amount of lime that existed in excess of that present as phosphate, amounting to 8·42 per cent. Since Mr. Mallet's return he has had a full determination made, giving 20·5 of lime, of which 18·5 was present as phosphate, representing 34·1 of this salt or 15·6 of phosphoric acid, being about a third of the total quantity present. The stone thus remains still principally a phosphate of alumina, but the difference is sufficient to call for a correction of the previous statement, as the phosphate of lime is the most important ingredient. The stones are described as occurring in some abundance and at many different places in brown shales immediately overlying limestone, so they may yet prove of economic value.

Of even greater interest, considering the failure hitherto to find fossils in any of the outer Himalayan rocks, is the announcement by Mr. Parsons (under date of 21st November 1884), that he has observed in the nodules what appear to him to be minute organisms. Preparations are in hand to investigate so interesting a discovery.

H. B. MEDLICOTT.

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Fossils from Nila in the Salt Range, Punjab, from the bed below the coal.
PRESENTED BY DR. H. WARTH.

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THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1885. [May.

A fossiliferous series *in the* Lower Himalaya, *Garhwal, by* C. S. Middlemiss, B A., *Geological Survey of India.*

This note is to put on record a find of fossils made by me in March from rocks of the Lower Himalaya of British Garhwal, all which have hitherto proved barren, save for comminuted fragments of shells[1] in the Mandhális known as the Tál limestone, a series which I have in addition shown to be the westward extension of these same fossiliferous rocks.

The find is not large, nor are the specimens all that could be desired in point of preservation; for frequently, owing to subsequent crystallisation and to oolitic aggregation, many have been spoilt.

Corals, Belemnites, Lamellibranchs, and Gasteropods, usually all of small size, form the staple of the rock contents, but writing, as I am, from the field, I can do no more at present than indicate their probable jurassic age.

The places I found most suitable for collecting are the northern slopes of the Dhalniya-ka-danda, at Gajwara[2] (Gujbara of map), and five miles to the west-north-west in a small ridge east of Umrela (Oomrela).

Petrology.

The petrological characters of the fossiliferous rock series are as follows:—In the main it is either a grit or a quartzite, with here and there a tendency to become calcareous or conglomeratic. Though some irregularities seem to show that the calcareous band is not constant in vertical position, and that the conglomerate varies very much in coarseness in different localities, still a good general sequence can be made out. The lowest rock, when seen, is of millstone-grit type, a good sound rather coarse-grained stone that would make excellent building material. The quartz grains are quite distinct, slightly angular, and of a milky-white or smoky colour; they are set in a pale-yellow earthy matrix, and on weathered surfaces stand out white against black

[1] Brought to notice in 1864 (Memoirs, G. S I, III, part 2, page 69).

[2] E lon 78° 42′, N. lat. 29° 47′ Sheet No. 7 of the 1 inch maps of Kumaun and British Garhwal.

in a way unlike any other rocks in this neighbourhood. The conglomerate merely differs from this by having the milk-white quartz pebbles of larger size, but still retaining their slight angularity. At one place near Aldabou I found a variety containing limestone pebbles in addition to those of quartz. Besides becoming conglomeratic in parts, this same grit, in nearly every section I have seen, has at one horizon, generally near the base, a calcareous element, which, entering into the composition by small instalments in the more eastern parts of the area under consideration, becomes more pronounced on the northern flanks of the Dhalniya-ka-danda, the ridge at Gajwara, and generally in the direction of the Tál limestone, with which it ultimately coincides. The greater or less quantity of lime present has not, however, destroyed its marked external appearance; in every locality it shows up as an indigo-black rock, very often forming a scarp some 30 or 40 feet high. It is never pure limestone, but always shows the blebs and grains of quartz; even where the limestone is most crystalline these can always be detected outside in relief, whilst the finer particles have become nuclei for oolitic grains which sometimes crowd the rock. This is the fossiliferous bed, and it has an average thickness of not more than 50 feet.

In an upward direction the coarse grit, bearing its limestone and conglomerates, passes by insensible gradations into a compact massive quartzite, white, or faintly tinged with violet. This has a large, but unknown, thickness. To the east-south-east at Chaprait (sheet No. 8), and the higher hills north, it is seen in force, but beyond I have not yet had time to trace it.

Stratigraphy.

Though in the future, when the fossils are identified, this rock may form a horizon from which to reckon beds stratigraphically associated with it, at present it is well rather to speak of it in terms of the formations above and below it, and more especially as the overlying one, a massive blue-grey limestone, has already a very probable equivalent in the Krol limestone.

Beds below.

But to commence with those beneath it. They are purple and green slates and an angular volcanic ash or breccia. From their invariable nearly vertical bedding it was some time before I decided which was the upper. At length a section in the Khoban river gave me the clue: there the ashes slack off their high northerly dip, and above them the purple and green slates arch over to the south, and helped by a fault, cover them in entirely for a short distance. This note does not profess to enter into details with regard to these beds. It is enough at present to say that they must have very great thickness, reckoned probably by miles; that the volcanic breccia is itself, certainly in places, a mile thick without any important constituent change; that though undoubtedly volcanic in origin, either direct or indirect, it possesses very few fragments of igneous rocks; nor is it associated with any outpourings of lava, nor with igneous intrusions, of which I have seen none in this area. Of the purple and green slates, it suffices here to say that they are very uniform until Kálogarhi mountain is approached. The mass of that height is Chor gneiss; [1] and from whatever cause, the slates on approaching it become altered in two modes—they level

[1] An intrusive rock.

out dipping only slightly towards the mountain on all sides, and they at the same time become schistose, schists, and garnetiferous schists.

Relation of the fossiliferous beds to those below.

It is now necessary to say what is the relation between the fossiliferous beds and those underlying slates and ashes, and also to fix some few definite localities. To this end the section up the Mandál river, and on the ridge west of it, in the neighbourhood of Dobriah, is absolutely conclusive. That in the river bed from near Dhámdhar to Jámri exhibits nothing but the ashes striking about east and west, the strata either vertical or inclined at angles of 80° and 70° either one way or the other. Not a yard of the distance is unexposed. The lower parts of the ridge from Dhargaon to near Chapprait are the same both on its east and west sides. But the numerous summits into which the ridge has weathered are all formed of an approximately horizontal capping of the pebbly grit with a calcareous lower bed. At this place, however, the lime in the rock is not abundant, nor did I get fossils, though they may nevertheless be there, for my find was subsequent to mapping this part, and I was not specially on the look-out for them.

If more evidence for the marked unconformity between these two series were wanting, it is found in the further extension of the pebbly grit and calcareous band along the ridge. At a point almost due west of Dhámdhar, where is a gap over into the Haldgadi river, they rest on the purple and green slates, which are striking east and west with a nearly vertical dip similar to the ashes.

Relation of fossiliferous beds to those above.

Here too it is seen that they underlie the massive blue-grey limestone which forms the top of Dhargaon. From Dhargaon a tolerably well-defined ridge runs west-north-west up to the Kotedwar glen cut through at intermediate places by the Haldgadi and Palain rivers. Its formation is the same throughout as at Dhargaon, with a slight exception: the north flanks have always the pebbly grit, with its calcareous band below and quartzites above in a continuous exposure dipping at 30° or 40° south-south-west, whilst the summit and southern flanks have the superposed massive limestone, which is cut off to the south by the main boundary fault letting in the later tertiary sand-rock. The exception is near the Kotedwar glen north of Aldabou, where the limestone, having gradually lost its hold on the ridge summit and become confined to the southern slope, is at last entirely cut off by the main boundary fault. Of course it must not be supposed that there are no slight disturbances affecting these relations: at Gajwara inversions of the fossiliferous beds complicate matters a little; but on the whole the steady strike and the absence of important structural faults render the sequence perfectly intelligible, notwithstanding the violent contortions and the heavy jungle which clothes the hills.

It is now necessary to return eastward of Dhargaon for an exposure of importance. Just as in a westward direction the limestone was gradually lost by the strike of the beds and the strike of the main boundary fault meeting near Aldabou, so eastward, on account of their divergence, the south edge of the limestone becomes free at Jhirt, and is seen to lie not upon the pebbly grits but upon the purple and green slates. This evidence so far as it goes argues an unconformable position for the limestone; but it might not be so; the fossiliferous

beds might, being conformable to the limestone, have thinned out; and this would indeed be plausible were it not for the great thickness which the quartzites attain north of Chaprait and Jámri, making it almost incredible that they could have thinned away to nothing in a distance of only 3 or 4 miles.

We have now seen that the fossil-bearing series lies in certain places unconformably above a set of slates and volcanic ashes, and unconformably beneath a massive blue-grey limestone of Krol type.

Relations with eocene beds.

But besides these local associations, there is another important one, *viz.*, the association with the nummulitic shales and limestone. The latter beds have been found up to date as far east as the Bodli-ka-sot, a tributary of the Palain river, where they lie, much folded, on the purple slates, and at several intermediate places between there and the Banás ridge. In consequence of the massive limestone series having vanished at Aldabou, the formerly subjacent fossiliferous beds have, in a westerly direction, their surfaces at liberty for still higher beds to occupy. Hence they become in this direction covered partially or wholly by the nummulitic clay-shales. Both series have indeed become in many places almost inextricably confused; for, starting probably with an uneven bottom for the tranquil deposits of the nummulitic sea, they have since been crushed together, causing the one to be displaced bodily, and the other to give by imperceptible folding and squeezing; whilst subsequent to all this, denudation has acted with a similar partiality, and land-slips have completed the ruin. For this reason it will be better to consider the two together in what I have further to say about them.

In the Kotedwar glen due north-north-west of Aldabou the main boundary fault of the usual reversed type cuts into the strata. North of it after some crush-rock and purple beds come the quartzites and calcareous beds vertical, and running as a minor ridge up to Umrela, beyond which in a gap in the ridge south-south-east from Charekh they dip at a rather low angle to the north-north-east, forming part of a synclinal curve, which again brings them to the surface with an opposite dip higher up on the ridge about 1 mile from Charekh summit. Below in the stream west of the ridge their continuous outcrop can be seen. Towards the Kotedwar glen the northern outcrop of this trough of the fossiliferous beds becomes lost, re-appearing again in the Kotedwar stream as a thin bed dipping south at the point where the Múhára and Kotedwar streams join. In this irregular broken-edged trough the nummulitic beds lie folded in a steep synclinal. They are very well exposed in the main stream, the Nummulitic limestone striking west-north-west along the mile reach between the points where the Umrela and Múhára streams flow into it. It is however impossible to realise this on the map, owing to this reach being erroneously drawn north-east and south-west.

The next point where these beds are seen is in the Sour glen, due west of Gaira and up the slope of the ridge north of Simalna. The trough has here lost its regularity, the calcareous beds and quartzites dip at 65° south-south-west in the Sour stream, climb the side-ridge towards Narai, and appearing here and there on the main ridge south of this return down the Simalna side-ridge. In the intervening side stream north of Simalna, and as pockets and films here and there

on the adjacent slopes, are placed the nummulitic clays and clayey shales. The main boundary fault is immediately south of Simalna. On the main ridge due north-north-west from Simalna a small peak displays a good section of the quartzites above and the calcareous beds below: dip north-north-west 40°.

In the bay between this peak and Shálni there is a great film of nummulitic beds which a surface land-slip distinctly revealed dipping down hill steeply. On getting out of this bay on to the Shálni ridge all the nummulitics were left behind except some few beds around the village itself.

Coincidence of fossiliferous bed with Mandhális of Banás ridge.

On visiting the ridge north-west of Banás-talla, in order to join my work with Mr. Oldham's, I found, as I expected, that the Tál limestone series, classified by him as Mandhális,[1] are the identical calcareous and sometimes conglomeratic grits and quartzites from which I have obtained recognisable fossils.

It is interesting to note in passing that so entirely have the nummulitics in this easterly direction retained their Sabáthu character that the pisolitic iron-ore of the bottom bed besides being present near Syair is vouched for in the Sour and Kotedwar glens by loose fragments with grains somewhat larger than a pea.

I do not propose to do more here than put these few facts on record. Though the somewhat extraordinary positions of the eocene beds offer scope for theorising and certainly must have important bearings in elucidating the mode of building of the Himalaya, I think it better to await further information in the same direction.

Note on the probable age *of the* Mandháli series *in the* Lower Himalaya, *by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*

That the discovery of recognisable fossils in Himalayan beds, recorded above by my colleage Mr. C. S. Middlemiss, will be of great value in establishing the age of at least one member of the Himalayan sequence, and in giving us a horizon to work from, cannot be doubted. But as in the meanwhile the acceptance as final of my ascription of the Tál beds to the Mandháli series might lead to misapprehension and confusion which would take long to pass away, I should wish to put the following explanation on record.

My identification of the Tál beds with the Mandháli series rested entirely on the discovery among the former of a bed of limestone conglomerate cemented by a limestone matrix, very similar to the one of most important members of the series as exposed at Mandháli in Jaunsár Báwar.

But the really characteristic feature of the Mandháli series is the occurrence of beds composed of a fine-grained matrix through which fragments, generally angular or subangular, of rock are scattered, the whole suggesting that the agency of floating ice was concerned in its formation.

No bed of this type was seen by me among the Tál beds, nor does my colleague mention the occurrence of any such bed in the area examined by him; and as the

[1] *Supra*, XVII, p. 161. See also the paper following the present one.

age he assigns to the Tál beds differs from that which on independent grounds I am inclined to ascribe to the Mandháli series, it will not be safe to accept the two as equivalent.

As mentioned above, the general appearance of the characteristic member of he Mandháli series and of the very similar Blaini conglomerate is that of an indurated boulder clay. In the latter case the resemblance has been noticed by other observers, and during the last working season a pebble was extracted from the Blaini conglomerate which showed very distinct striation similar to that generally attributed to glacial action. Though this corroborative evidence has not yet been obtained in the case of the Mandháli conglomerate, it very probably is also of glacial origin.

I have elsewhere expressed an opinion that these old glacial boulder clays are of great value in determining the homotaxy of the beds among which they occur, and that they are at present the only means by which it can be determined with anything like absolute accuracy. But whether or no this opinion will bear the test of subsequent examination, there can be no doubt that between neighbouring areas the method is perfectly valid, and we may take it as practically certain that when the glacial boulder clays of Talchir age were being deposited in what is now the peninsula of India, glacial conditions must have obtained over what are now the Himalayas.

In the beds of the Himalayan sequence there are three distinct horizons at which similar beds are found, *viz.*, (1) the Mandháli, (2) the Blaini, and (3) the Panjál conglomeratic slates. Of these, the two last named are so low in the series that their contemporaneity with the Talchirs is practically out of the question; there remains only the Mandháli conglomerate which we may therefore take as most probably the equivalent of the Talchir beds of India.

But the Talchirs are at the latest of triassic at the earliest of carboniferous and probably of permian age as judged by European standards; and we must for the present refrain from finally identifyng beds which are very probably of the same age with other beds containing such a characteristically mesozöic fauna as is described by Mr. Middlemiss.

Note on a second species of Siwalik Camel (*Camelus antiquus, nobis* (*ex* Falc. and Caut. M. S.), *by* R. LYDEKKER, B.A., F.G.S., &c.

In their original notice of *Camelus sivalensis*, Falconer and Cautley[1] said they had evidence of a second and smaller species of the genus from the Siwaliks which they proposed to call *C. antiquus;* but in the subsequently published plates (Nos. LXXXVI to XC) of the "Fauna Antiqua Sivalensis" all the remains are figured under the former name. A recent examination of the specimens in the British Museum has convinced me that the original view is in all probability correct.

Camelus sivalensis is a large species characterized by the rugose enamel of the teeth, the flatness of the inner walls of the lower true molars, and the

[1] *Vide* 'Falconer's Palæontological Memoirs,' Vol. I, p. 231.

long, slender, horizontal ramus of the mandible. The second species, for which I propose to revive the M. S. name of *C. antiquus*, is of smaller size, has a short, deep mandible, perfectly smooth enamel to the teeth, while the inner surface of the lower true molars is concave, and in its upper half is divided into two equal portions by a median vertical ridge, totally wanting in *C. sivalensis*,[1] and the existing camels. The specimens in the British Museum which can be referred to the new species are a maxilla, No. 15347; a young cranium, No. 40562 ("F. A. S.," pl. LXXXVI, fig. 2); part of a mandible, No. 16165 ("F. A. S.," pl. LXXXVII, fig. 5): another fragment of the mandible, No. 40568; and the greater part of a right ramus, No. 39599, with the teeth broken. At least one fragment of a mandible in the Indian Museum belongs to the same species.

I may also observe that both species of Siwalik camels are characterized by having the vertical ridge at the antero-external angle of the lower true molars which occurs in *Auchenia* but is absent in the existing camels. Both fossil species have the adult dentition numerically the same as in the existing ones; but at least one of them is distinguished by having the full complement of milk-molars in both jaws, *viz.*, M. M. $\frac{4}{4}$. The cervical vertebræ of the larger Siwalik camel are in some respects intermediate between those of the living camels and *Auchenia*.

Some further notes on the Geology *of* Chamba. *By* COLONEL C. A. MCMAHON F.G.S. (With a plate and map.)

CONTENTS.

PART I.

DESCRIPTION OF A PORTION OF THE CHAMBA AREA PREVIOUSLY UNDESCRIBED.

In detailing some observations in the field made during the autumns of 1883 1884 I think the most convenient plan will be to note them in the order of the places visited.

I proceeded in a northerly direction from Dalhousie to Bhale (Balai) and Manjir (Manjere), and thence to Bhándal (Baundal). This section has already been described in a previous paper, and only a few additional observations will now be made.

[1] In the 'Palæontologia Indica,' ser. X, Vol. I, p. 61 (43), I gave these points as being characteristic of the molars of *C. sivalensis*, not being then able to notice the difference from typical specimens in those I had before me.

There is a superficial appearance of bedding in the outcrop of the "outer band" of gneissose granite, but I think it is only due to irregular jointing. The joints that run in the direction of pseudo-foliation are not continuous, but die out or run into each other.

Along the southern margin of the *inner* band of gneissose-granite the slates in contact with it are indurated, and I noted a small vein of granite intrusive in the slates near the swing bridge ("jhula") under Bhale.

On the northern margin of this outcrop of the gneissose granite, I observed some mica schists next the granite, but an examination of thin slices under the microscope has satisfied me that they belong to the margin of the granite itself. I can discover no essential difference, save in macroscopic aspect, between these schists and the gneissose granite. There is nothing surprising in the fact that the margin of the intruded sheet in contact with the slates should have assumed a specially schistose aspect.

In a previous paper I described the narrow outcrop of the gneissose granite below Bhale. I have now examined several slices made from specimens taken from the sides, middle, and intermediate parts of the sheet, and the result is to confirm me in my belief in its eruptive character. No points of difference exist between it and the Dalhousie granite, and it reminds me in particular of slice No. 15, described at page 132 of my paper in Vol. XVI of the Records. These specimens exhibit beautiful illustrations of the sort of fluxion structure detailed in my description of the Dalhousie specimens. The flowing lines of crypto-crystalline mica and of microlites do not at all suggest to my mind the appearance presented by foliated metamorphic rocks.

The orthoclase is much cracked and crushed; and the muscovite, which is in large crystals, is oriented in all directions, and appears to have been abundantly crumpled and compressed.

The minerals contained in the rock are the same as those in the Dalhousie specimens, though the microcline is sparse.

There are liquid cavities, with movable bubbles in the quartz, but they are much more abundant in the garnets, which probably crystallized at an earlier epoch, before the last phase of intrusion commenced. Inclusions have deposited mineral matter on cooling, and gas pores are associated with granular mineral matter.

The slates between the inner and outer bands of gneissose granite, in this section, are very micaceous, and at Bhale they are decided mica schists.

Between the northern boundary of the inner band of gneissose granite and Manjir, the succession appears to be as follows—micaceous slates; mica schists; slates; micaceous slates; slates; micaceous slates; slates.

I think in this section the Simla slates are folded up with older silurian beds in compressed isoclinal flexures. The decided mica schists are probably beds near the bottom of the series.

Just before the descent to the river Siul commences in the neighbourhood of Balori, I observed river conglomerate at an elevation of 3,320 feet above the sea, being over 800 feet, by my aneroid barometer, above the Siul. In the neighbourhood of Biláspur, the capital of a Native State, south-west of Simla,

I found river conglomerate[1] on an isolated hill, round which the Satlej flows, 980 feet above that river, and in my "Notes of a tour through Hangrang and Spiti"[2] I mentioned the occurrence of river boulders at the top of the Chandan Námo pass at an elevation of 12,340 feet above the sea, and about 2,400 feet above the present bed of the Spiti river. The explanation I offered, in the latter case, was that the Spiti river was formerly as high as the top of the Chandan Námo pass, but I now see that this explanation was incorrect. Whilst the Himalayan rivers were slowly deepening their channels and excavating the valleys through which they flow, the mountains themselves, there is reason to believe, were slowly rising at a rate probably equal to that of sub-aerial erosion. In the case of the river Siul, therefore, though it has undoubtedly cut its way through 800 feet of solid rock, there is no necessity for assuming that the river ever actually flowed at the elevation at which the boulder bed now rests.

I always thought that the elevation theory was necessary to explain the present position of the Satlej boulder beds in the neighbourhood of Bilāspur, but I now see that it is applicable to boulder beds generally throughout the Himalayas.

The fact that the Himalayas have been slowly rising[3] whilst the rivers have been deepening their channels, explains, I think, why the Himalayan valleys are generally so steep and V-shaped.

The cause of the rising of the Himalayan area, which is probably still slowly going on, is discussed at length in the Revd. O. Fisher's Physics of the Earth's Crust.

Whether, however, the elevation of the Himalayas in most recent geological times is due chiefly to the flotation tendency assigned by Mr. Fisher, or to tangential pressure acting on an area losing weight from sub-aerial erosion, is a subject foreign to the scope of this paper. I am only concerned with the fact of elevation.

Geological observations to support the view that the Himalayas have risen in recent geological times, are not wanting; for instance, the "remains of *Rhinoceros* and other large mammals occur at an elevation of 15,000 feet in Tibet, and it is not probable that these animals lived in so elevated a region" (Manual of the Geology of India, p. 586).

From Bhándal I followed the Siul river as far as Sangni, and then turned up the valley leading to the high ridge between the Talai and Paterun[4] trigonometrical stations.

The valley is at first narrow, and the scenery all the way up it is extremely pretty. The foot-path runs for some distance along the banks of a roaring torrent through woods of hazel and horse chestnut; and then, mounting higher, passes along sloping pasture lands; and finally plunges into the dark shade of a

[1] The top conglomerate contained Satlej stones only, such as white quartz schist from Rampur, gneissose granite, purple and red quartzite from the upper Satlej or Spiti, and black basaltic-looking trap.

[2] Records, XII, p. 66.

[3] Physics of the Earth's Crust, p. 81.

[4] Not marked on the map which accompanies this paper. Paterun is the peak between Tala and Dunrat stations.

pine forest, in which the holly oak, stunted and weather beaten, seems to have a hard struggle for existence. Higher up, the forests cease, and a dwarf rhododendron is the only tree that bears the cold of that high elevation, though many flowers brighten the grassy slopes.

Among them a wild poppy of delicate purple blue merging into white is not the least beautiful; whilst a yellow flower, greatly resembling the English buttercup, reminds one of the home so far away. I have not observed the poppy at a lower elevation than about 11,000 feet.

Wild rhuburb abounds at the head of this valley. An officer of Artillery, on a shooting tour, whom I found encamped at Ghamkol,[1] told me that he used the rhuburb almost daily for tarts and found it good and wholesome. My friend, however, seemed somewhat bold in his gastronomical experiments, for I found that he was in the habit of putting many species of tree fungi under contribution for the table. The natives of these parts told him that all the fungi that grow on oak are wholesome, but that those that grow on pine trees are to be avoided. He induced me to try a slice of a huge yellow oak fungus. It had a faint suspicion of mushroom flavour in it, and was not unpalatable. On opening my eyes next morning I was thankful to find myself still in the land of the living.

After leaving Sangni the silurian conglomerate continued up to where the second affluent joins the main stream from the north-east. I saw numerous outcrops *in situ* as well as blocks of it. The dip was north-east, nearly vertical, with an occasional reverse dip. Subsequently the dip became more moderate.

As in other sections described, the conglomerate is not uniformly conglomeritic, but includes slaty bands. The conglomerate is succeeded by dark slates, some of which have a dark streak, and doubtless belong to the infra-Krol series.

Higher up the valley the dip became south-west and south-south-west, but finally reverted to north-east. On my way I came upon boulders of conglomerate, and near my encampment, at a place called Ghamkol, at the head of the valley (elevation 10,630 feet), and near the boundary of the trap, there are some thin beds of pale blue limestone. Above these beds, and between them and the trap, I came on conglomerate *in situ.*

At the very head of the Sangni valley, a long spur will be observed, on the map, running down from the water parting of the Bhadarwár (Badrawár) and Chamba territories, and dividing the head waters of the valley into two streams of about equal size. The trap comes in where this spur joins the main ridge, or water parting; it dominates the crest of the ridge for some distance and then strikes down in a broad band and joins the outcrop described in a previous paper between Tiloga and Dihur (Duire).

All along the north-eastern boundary of the trap down to Dihur the silurian conglomerate is in contact with the trap. The Paterun station[2] peak (elevation 12,260 feet by my barometer) is on the conglomerate. The trap just skirts the

[1] Not marked on the map. It is just under the crest of the ridge dividing Bhadawár from Chamba close to the outcrop of the trap.

[2] This is not marked on the map that accompanies this paper. It is the peak south-west of the Dunrat station at the point where the ridge strikes in a north-westerly direction to the Talai station.

edge of the ridge and keeps on the south-west side of its crest until the spurs running up from Bhándal meet the main ridge and culminate in a peak 11,755 feet high, where the trap rises to the crest of the ridge and forms the rock along its summit for some miles.

The trap along this ridge is very much jointed, the principal joints being transverse to the strike; and it affords instructive illustrations of the power of frost in combination with jointing to break up rocks. The very crest of the narrow ridge, which runs at a tolerably uniform elevation for some distance, is formed of a mass of sharp angular blocks of trap piled up one upon another, four, or five, or more deep, in the manner of a moraine, with deep holes gaping between them. A sharp shock of an earthquake, on my return to my tents, supplied a hint that seismic disturbances ought not, perhaps, to be altogether left out of view in accounting for the piling up of large blocks of rocks one upon another in the manner described.

The route I followed took me along the south-west boundary of the trap from the head of the Sangni valley as far as the spur running down to Digi.

It is a fine country, but as my tents were often pitched at an elevation of more than 10,000 feet above the sea, I found it cold at night, and two days after I descended to a lower level, my late camping grounds were white with snow.

The ridge at the head of the Sangni valley commands a fine view of a range of snowy peaks rising to over 21,000 feet in height, whilst my camp was usually pitched on grassy slopes, abounding in flowers, just above the limits of the dark pine forests that clothe the mountain sides lower down.

Bears, red and black, and Bára Singha (*Cervus cashmirianus*) allied to the red stag of Europe, and Tahr (*Hemitragus jemlaicus*) are pretty numerous, and I often saw their recent foot-prints, but not the animals themselves. During the summer months these grassy slopes support large herds of buffalos and sheep which are driven down into the plains of the Punjab when the cold season begins to set in. Sportsmen have a poor chance of a bag until these herds have departed.

Along the south-west boundary of the trap the rock in contact with it appears to be the silurian conglomerate. No reliance is to be placed on blocks as they might be derived from the outcrop on the other side of the trap, but I believe I saw the conglomerate *in situ* in two instances. The dip is usually north-east, but occasionally changes to the west.

The trap along the outcrop, described in the preceding pages, here and there passes into a porphyritic variety. It is a hard, dense, compact rock, ranging from a dark purple-grey to a dark greenish-grey colour. Numerous crystals of felspar are porphyritically imbedded in the dark base. Further remarks regarding the microscopic character of the trap will be found in Part II.

My return route to the Siul was along the spur which runs down from the main ridge to Digi.

The slates dipped from north-east-by-north to north-north-east, very high, and with an occasional reverse dip. They were of silurian type and not visibly conglomeritic, but as the outcrops were mostly the up-turned edges of the strata,

opportunities of judging of their conglomeritic character were bad, for the pebbles are seen for the most part when the splitting surfaces of the rock are exposed.

About 600 or 700 feet above Digi I came upon a narrow calcareous band, the beds being earthy to slaty.

I have now made three traverses west of the outcrop of the carbo-triassic series seen typically below Dihur, *viz.*, up the Sangni valley, down the Digi spur, and from Himgiri to Digi; and in none of them did I come across any thing like the carbo-triassic limestones. The calcareous band above Digi, and the thin bed of limestone near Ghamkol, probably belong to the Blaini or to the infra-Krol horizon.

The carbo-triassic limestones extend very little to the west of Duta. Infa-Krol slates and the black crush rock are seen at and near the bridge over the Siul below Kotta. A thin band of these rocks may extend up the river as far as Pal, and some of them are doubtless implicated in the isoclinal folds between the outcrop of the trap and Bhandal, but the carbo-triassic limestones west of Duta have either been squeezed out in the plications in which the silurian series have been involved, or the area of deposition terminated at Duta.

Another point brought out by the field observations detailed above, is that the outcrop of the conglomerate on the south of the trap is as broad as that already mapped on the north of it. South of Manjir some of the streams running down from the north-west into the Siul contain blocks of conglomerate, showing that this formation is wide enough, south of Dihur, to overtop the crest of the ridge between Ain and Gutaun.

From Manjir I crossed the Siul and proceeded along the spur which culminates in the Dwaut trigonometrial station, and then made for the head of the valley under the Rundhar station.

Simla slates dominate along the crest of the ridge, but the conglomerates come in about half way down the north-eastern side of the ridge above the village of Mahdeb[1] (not marked on the map). The bed of the stream contains numerous boulders of typical conglomerate. The dip varied from south-south-west to a little east of north-east along the ridge, but in the valley under Rundhar from east-north-east to north-east-by-east.

The trap crops out under the village of Bhōlu (not marked on the map), and is here about 100 yards wide. It is succeeded by the carbo-triassic series which is here in great force and very typically developed. The rocks in immediate contact with the trap are very micaceous carbonaceous slates; then follow dark-blue unaltered limestones; these are succeeded by very micaceous ates; thin bedded unaltered limestones occur next and then micaceous slates ollowed by limestones.

These mica slates deserve, I think, some notice. Their micaceous character is clearly not due to contact metamorphism,[2] for those at a distance from the trap, and intercalated between unaltered dark-blue carbonaceous limestones, are

[1] A local corruption doubtless of Máhádeo.

[2] The trap according to my view is an ancient lava and older than the carbo-triassic series, so that beds of the latter cannot possibly have been metamorphosed by the trap.

as micaceous as those in contact with the trap. These micaceous slates—mica schists they might well be called—suggest, I think, the conclusion, that the metamorphism of the type which consists in the formation of hydro-micas—or micas of the species usually developed in slaty rocks—may be brought about by aqueous or hydro-thermal agencies, accompanied by a very moderate amount of heat. Here we have highly micaceous slates intercalated with dark carbonaceous limestones that give no trace of having been subjected to heat.

The outcrop of the trap in this region runs with the southern boundary of the carbo-triassic series. In the north-westerly direction the trap evidently extends beyond Bailaum to near Sanaira, for the stream that flows under that village into the Siul contains boulders of it. No outcrop of it is to be seen on the Kalel road or between Manjir and Dihur.

In its south-easterly extension, the trap runs past Chanena (not marked on the map); and crossing the ridge west of Hulh (Hul), makes for Kail and Dila. It tops the ridge east of Hulh above the village of Dhar, and then striking for Amraili crosses the Sao valley about three-quarters of a mile north of Sao. The outcrop is here about 200 to 250 yards wide.

The carbo-triassic series continues in contact with the trap across the Hulh and Sao valleys. In ascending the latter valley the last of the series seen appears to be a massive grey quartzite. The dip is north-east-by-north.

The carbo-triassic series is succeeded by a very fine-grained massive silicious rock of grey colour that gradually passes into massive slates. Some of the former weather brown and some greenish, and they have superficially a trappean aspect; they are also extremely tough and hard to break.

I explored the Sao valley for some distance beyond Lolaya in the direction of the glaciers at its head and then returned to Sao. The next day I proceeded up one of the side valleys in order to cross the high range that divides it from the Chánju valley. The first march took me to Sarrah (elevation 7,140 feet), a village not marked on the map. Dip perpendicular. The next day's march was rather a severe one, but fortunately I engaged ten extra coolies for my things; had I not done so I should not have seen any of them by nightfall. First we had a stiff ascent to the summit (11,525 feet above the sea), and then a walk for some miles along the ridge. No suitable place for an encampment presented itself, as the nearest water was about 700 or 800 feet below us, and firewood was almost as distant. We pushed on down a precipitous descent for some Gujar huts about 3,000 feet below, which we reached about 5 in the afternoon. The spot was indeed a lovely one—a grassy glade in a pine forest with the peaks and glaciers of Kailu and Kalka well in view; but alas the Gujars with their herds had left the spot, the streams had dried up, and no drinking water was to be had within a radius of $1\frac{1}{2}$ miles. There was nothing for it but to push on for the nearest village, Sundri (Sundor), 3 miles further down the mountain, which I reached at dusk after walking for 11 hours, climbing 4,385 and descending 4,525 feet.

The first thing to be done was to send back men with torches for the coolies, who finally arrived without serious accident, my crockery only coming to grief by the way.

The march, though long, was a delightful one. From the crest of the ridge, the Kailu (18,639 feet in elevation) and its twin peak Kalka with the glacier between them, 8 miles distant as the crow flies, formed a beautiful subject for a picture. A snow-storm was going on in the back ground; the warm sun gilded the rich red and brown autumnal tints of the foreground; whilst checkered and ever changing lights and shadows were playing over the forests and the grassy slopes of the middle distance. The clouds tipped the peaks and cast their deep shadows over most of the snowy masses around; whilst the sun, bathing the glacier of Kailu in light, made it, by its contrast with the gloomy masses by its side, look like the portal of a heavenly world beyond.

At the village of Sundri there was not a square foot of available level ground, all the terraces being under crops, and so I had to pitch my tents on the flat roof of a house. The process of washing my face and hands in the morning was a source of great delight to a group of village maidens, who in these mountain villages seem wholly unacquainted with the cleansing properties of soap and water.

Between Sao and Sundri (Sunder) I saw nothing of the conglomerate; on crossing the stream under Chánju, however, I came on blocks of it, and encountered them in nine different places between that and Bagai. These blocks were not *in situ*, but they appeared to be fragments of the local rock with which the matrix of the conglomerate quite corresponded. The dip was at one time south but afterwards reverted to the normal direction. Below Bagai, on the left or south bank of the river, I found the conglomerate *in situ* twice.

From Kalel the conglomerate appears to strike nearly due east for Bagai and to continue thence towards the Chara Pass, where I am told that it occurs by Dr. Hutchinson of Chamba.

In the course of the plications in which the Chambà rocks have been involved, silurian rocks, lower in the scale than the conglomerates, appear to have been brought in between the latter and the carbo-triassic series, which in the Manjir-Kalel section is in contact with the conglomerates on both sides.

The dip between Bagai and Jasaor is about south-south-west.

On the Kalel and Balore road, on both banks of the river that flows between Daund and Balore, I came upon numerous blocks of the conglomerate (they are very abundant in the bed of the stream); and though, owing probably to the abundance of vegetation, I did not find any actually *in situ* on the ascent to Masrund,[1] I doubt not that the conglomerates, which are visible *in situ* in numerous places round Manjir, and which we have seen in the preceding pages, are abundant along the head of the Bailaum valley, are continuous between the two places.

During the summer of 1884 official duties led me to Simla, and I was unable to carry out a projected tour in Pángi; Dr. Hutchison, of the Chamba Mission, however, kindly undertook to make observations for me, and in particular to mark the boundaries of the silurian conglomerate. His notes are given further on.

[1] A halting place not marked on the map.

On my return from Simla I was able to make a short tour up the Káli Cho (Kali Chu) valley, in November, and I now proceed to give the results. Our party consisted of Dr. Hutchison, my wife, and myself. We proceeded eastwards from Chamba up the Ravi to a point opposite Basu, when we turned northwards and journeyed *viâ* Guh up the Belij (Bailj) valley as far as Kanaiter. A very stiff climb of 5,200 feet from our encamping ground in the bed of the stream, under Bulote, took us to the top of the Kanaiter pass, which we crossed at an elevation of 10,125 feet.

The hill sides were white with snow and the tracks of bears, probably the red bear, were rather numerous. Our route lay just under the Thala station, and we crossed the second ridge running down between Oure and Thala (Thale) at a high elevation. We encamped at the Dul,[1] a level plot of land that must once have been a mountain tarn, just above the junction of the stream flowing from the Silpiri station and the highest stream running into it from the north-east.

The march was a somewhat trying one, and though we started early our coolies did not get in until long after nightfall. About dinner time the sad news was broken to us that all our crockery had been left behind at the top of the pass; that the coolie carrying the load had given himself up for lost, and had sat down to cry; and, that as he was deaf and dumb, the eloquence of our servants had been exerted on him in vain.

Parties with a lantern and torches were sent back to aid those behind, and finally all our men arrived without accident.

The Dul we found to be interesting from a geological point of view: it is evidently a dried up tarn, and the mode in which it was formed is not far to seek. The bed of the dul is bounded on the south by what appears to be an old moraine. It rises abruptly from the bottom of the dul to the height of about 60 feet, and on the outer side, descends at a high angle to a considerable depth into the ravine below. This bund runs in a straight line at right angles to the course of the stream, which has cut a narrow channel through it, at one side of the little valley, at its junction with the solid rocks. The bund is apparently formed of angular blocks of rock; there is nothing in the conformation of the hill sides around to suggest the possibility of a land slip, and a careful inspection of the locality convinced Dr. Hutchison and myself that the bund is an old terminal moraine, and that the ancient tarn was formed by the shrinking of a glacier that has long since disappeared. The elevation of the Dul, measured by my aneroid, is 7,825 feet above the sea.

Our onward route was *viâ* Guar and Tanda to Chalaur, and thence through Manda and Bani along the right bank of the stream until we came abreast of Badra, when we crossed to the opposite side.

The last 3 or 4 miles of this march illustrates well the general character of the roads traversed during the whole of this tour and the kind of walking that the Himalayan geologists must be prepared to encounter. Our route lay along the precipitous sides of the mountain; the path was not more than 9 inches wide; a fringe of grass along the edge seemed to invite the foot but gave

[1] On the accompanying map the Dul is just below the O of the elevation of the Thala station 12,208 feet).

way the moment it was trodden on. A fall would inevitably be fatal, for there was neither tree nor bush to save you, and the mountain side sloped down to the river, some 1,500 feet below, at so high an angle, and was clothed with grass so slippery, that nothing could have saved a man once in motion downwards.

This was varied every now and then by rock work along precipices where you needed to use your hands, as well as your feet, and to be clever in prospecting your way.

The trying part of the march, however, came as a *bonne bouche* at its end. The torrent under Budra has cut a deep narrow gorge through the mountain; descent to the water's edge was impossible, and the only way to cross the stream was by a frail bridge stretched from rock to rock some 150 or 200 feet above the roaring torrent below. The bridge was formed of three poles about 30 yards in length, and across them small roughly hewn planks were fastened with twigs forming a roadway of about a yard in width. A plank was dangling by one end over the chasm below, leaving a gap in the roadway, and suggesting painful doubts regarding the stability of the rest of the structure. The bridge had neither railing nor hand ropes.

There was nothing to be done but to face the bridge, and so I mounted the pile of stones that kept the poles at one end in their places and started. I must confess that when I neared the centre my heart failed me, and I felt horridly tempted to turn back, but a moment's reflection convinced me that if I attempted to do so I should probably topple over, and so I strode onwards with hastened step and cleared the bridge with great thankfulness.

Now came my wife's turn. My guide doubted her being able to retain her presence of mind, and wanted to bandage her eyes and carry her over on his back, but she disdained to accept this mode of progression and walked over with steady and unfaltering step.

I was not surprised to find that one of the laden hillmen who arrived whilst I was resting at the bridge was unable to face it, and a man with a better head was obliged to cross over and relieve him of his load.

From Budra we proceeded up the stream as far as Luindi, a hamlet of three huts, the highest inhabited place in the valley. The season was too late to proceed any further, and there was no object in our doing so, for an inspection of the boulders in the bed of the stream, flowing down from the Káli Cho, showed that no new rocks come in between Luindi and the crest of the pass.

Our return route was along the left bank of the stream *viâ* Baragrao and Tatahu to Kani, on the right bank of the Ravi, and thence to Aulansa (Hulans). On a previous occasion[1] I proceeded from Aulansa to Chamba *viâ* Kote, but on this occasion we struck down to a new road in progress of construction along the bed of the Ravi, as that gave good exposures of the rocks.

From Bakaun I went up the stream running to the west of the Basu station and marked the boundary of the outcrop of gneissose granite there. In this region it is a porphyritic and perfectly granitic rock.

Having described my route, the rocks seen by the way can now be noted. The conglomerates crop out under Guh (north of Basu) and continue typically

[1] Records, XVI, 38.

developed to the point noted on the map. They dip under limestones that remind me somewhat of the Blaini rocks, and which, like them, effervesce slowly with acids. The outcrop is about 100 yards thick, and it is followed by slates, some of which are rather dark. Limestones succeed at the stream to the south of Puger. These effervesce freely with acids. From this point up to the head of the valley the rocks are silurians, *viz.*, what appear to be Simla slates and fine-grained silicious beds, many of the latter being superficially of trappoidal aspect similar to those north of Sao.

In this section the lower silurians are nowhere reached. The apparent thickness of these beds is very great, but the rocks are, I think, repeated by flexures.

On the homeward journey we carried these silurians with us all the way to Kani. Just below this village the carbo-triassics come in. On the descent to the Ravi we noted five outcrops of them intercalated with slates; the first outcrop being about 300 yards in thickness. The limestones here are very earthy, and for the most part so shaly in appearance that the hammer and acid bottle had to be in constant use. A casual traveller might easily overlook these outcrops altogether.

The limestones are succeeded by the conglomerate; the limestone in actual contact with the latter weathers brown and effervesces slowly with acids, reminding one in both respects of the Blaini magnesian limestone.

The outcrops of the conglomerate between Aulansa and Chitrali (Chitrahi), along the Koti road, have been described in a former paper. Descending to the Ravi, I noted an outcrop of trap in the slates near the border of the conglomerate. It is only about six yards wide, but it appears to be interbedded with the slates, and to be on the same horizon as the Sao trap.

The conglomerates exposed on the new road are, as usual, not continuously conglomeritic, but they are seen typically developed on both margins and at least one other intermediate place. The total apparent thickness of the series is very great, and one must either suppose that the period during which the conglomerates were laid down was of great duration, and that the conglomeritic period recurred more than once, at long intervals, under conditions precisely similar to those of the first deposition; and that the rocks under denudation and the mode of deposition were identically the same on each recurrence of the conglomeritic period; or we must suppose that the thickness of the conglomeritic series is apparent only, and that the conglomerates are repeated by folding and flexures.

The latter supposition is the one I have adopted. The section along the river presents much to support this view. Dark slates, which are probably infra-Krol, are, I think, folded up with the conglomerate, whilst a very peculiar rock is undoubtedly reproduced. This is a very white rock which at first sight seems to be calcareous, but it refused to effervesce with acids.

Among the beds folded up with the conglomerates is a rock with dark bands in it that presents some interesting and instructive examples of small local faulting.

Throughout the area embraced by my tour of November 1884, the dip of the strata is uniformly north-easterly. From Kanaiter to Guar the dip is very high and in one place quite perpendicular. Opposite Budra the strata on the top of the mountain present to view a flat wavy synclinal flexure, whilst the beds

below are in some places almost perpendicular, and in others crumpled into sharp folds like the capital letter M. At first sight one might suppose that the strata on the top of the mountain opposite Budra rested unconformably on the perpendicular and contorted rocks below, but I feel sure that this appearance is only the result of the great lateral pressure to which the rocks have been subjected, and is to be explained in the way suggested in my first paper (Records X, pp. 208, 209). The present contour of the mountains having been determined before the last Himalayan disturbances took place, the strata in the direct line of the squeeze naturally suffered more than the strata above that line.

The explanation which I have given in Part III of this paper of the section through Hulh (Hul) applies, I think, to the stratigraphy of the Belij and Káli Cho valleys, the only difference being that the silurians in their south-easterly extension have been involved in more flexures than those in the Sao section—their apparent thickening being due to this cause; and the Simla slates have been in the Belij section introduced next the carbo-triassic series, and are probably repeated further north.

The following notes on the geology of the Pángi valley south of Kilar have been written for me by Dr. Hutchison, and contain the results of his observations this year:—

"As far as the village of Haile,[1] the silurians continue with a low south-west dip, and beyond this a north-east dip sets in. About 3 miles north of Haile, where the second nallah from the north joins the main ice stream, the micaceous schistose beds give place to the Blaini conglomerate with white and grey quartz pebbles, which however did not seem to be very numerous. A little farther north the rocks are coloured with iron oxide, but they seemed to be of the same character as the conglomerates. Proceeding towards the Cheni (Chaia) pass the conglomerate rocks still continued, and were in places well marked; and the main ice stream contained numerous boulders of a conglomeritic character. About 2 miles from the top of the pass these rocks began to be mixed up with rocks of a slaty appearance and non-conglomeritic; and the top was composed of slates of much the same appearance and character as the coarse slates used for roofing. The dip from Haile to the summit was north-east at a low angle, getting higher and higher near the top; and a mile to the north of it the strata became quite perpendicular, and continued so till the Chandra Bagha river was neared when a high south-west dip set in. About half-way below the top of the pass, and the junction of the ice stream with the Chandra Bagha, there is a very well marked outcrop of conglomerate about half a mile or so in thickness. The rocks between the top of the pass and this outcrop did not seem conglomeritic, but I suppose they must be regarded as belonging to the conglomerate series. North of this point the rocks seemed silurian—micaceous and quartzose schists and slates.

From near Kilar to a point one mile south of the Mocha stream the rocks are silurians with a south-west dip. South of this there are two very narrow bands of a pale blue sub-crystalline limestone, each 9 or 10 feet thick. Succeeding these is a well-marked outcrop of conglomerates which continue to a point opposite the village of Phinphar. Throughout a considerable portion of this distance the road is partly cut out of the solid rock and partly supported on crowbars fixed horizontally into the face of the perpendicular cliff. The matrix of the conglomerate is micaceous schist, and the contained boulders are chiefly of white quartz, some of them as much as 9 inches in their long diameter. These rocks are succeeded by silurians with a south-west dip getting higher and higher till the strata become perpendicular to the south of the Cheni stream and opposite the village of Kalaul; and they continue so as far as the village of Sugwas. Here a band of limestone comes in, 140 feet in thickness, of a dark colour, soft and friable. Next come slaty rocks for half a mile or so, and then another band of limestone, sub-crystalline in texture,

[1] Haile is on the north side of the Cheni (Chaia) pass north of Debi Koti.

and also about 140 feet thick. This is followed by well-marked conglomerates, full of pebbles which continue nearly as far as the point where the river bends round to the south. The dip opposite Sugwas is still vertical, but beginning to incline to the north-east, and this inclination becomes more marked as the southern border of the conglomerate is neared. Next come micaceous and quartzose rocks with a moderate north-east dip till after crossing the stream coming down from the peak marked "snowy peak black cone 17,145 feet" and half way between that stream and the one to the south of it the conglomerates come in again and continue till the stream from the Drati pass is neared. The rocks abound in pebbles of white and grey quartz, and the rocks on the other side of the river are seen to be also conglomeritic and weathering a very black colour near the margin of the water. In the bed of the Drati stream the rocks are greenish in colour and not conglomeritic; they look like middle silurians. These continue with a moderate north-east dip to within a short distance of the large stream which joins the Chandra Bagha from the south—midway between Tindi and Silgraon. Here well-marked conglomerates come in again with pebbles of white and grey quartzite and granitoid gneiss, the latter becoming more numerous near Silgraon encamping ground. They have a north-east dip and continue to within a mile of the point marked "bridge" on the map. Immediately above the bridge and on the left bank of the river are seen (from the opposite side) several large blocks of quartzite from 2 to 3 feet long and 8 or 9 inches thick embedded in the slates beyond the border of the conglomerate.

These silurian slates continue on into Lahoul, the dip becoming perpendicular between Silgraon and Margraon and inclining over to the south-west beyond Triloknath. In the stream to the south of that place, there are many large and typical boulders of conglomerate, but I nowhere saw the rock *in situ*.

On my return journey I crossed the Drati Pass, but found no rock which appeared to me conglomeritic till I came within a mile of Chanju. The Chara Pass is I know composed of conglomerate which seemed to me, when I crossed it two years ago, to extend continuously from half way down the northern side of the pass to the village of Bagai (Baghi) below Chanju."

I have marked the outcrops of conglomerate noted by Dr. Hutchison on my map in consultation with him, and these outcrops I have connected with those observed by me on the north-east side of the Sach Pass, and on the western side of the snowy chain.

Dr. Hutchison believes that the outcrop at Phinphar (the most northern outcrop marked on the map, a little to the south of Kilar) is continuous with that which crops out on the north-east side of the Sach Pass. The latter outcrop, he believes, splits into two arms—one curving round to Phinphar, and the other joining hands with the outcrop at Sugwas. The latter supposition does not seem open to any doubt, as the conglomerate has been seen *in situ* by Dr. Hutchison on both sides of the Cheni (Chaia) Pass, and its boundaries on both sides of that pass have been carefully noted.

It is not improbable that the outcrop on the north-east side of the Sach Pass splits up in the manner suggested. The apparent thickness of the conglomerates I have all along supposed to be owing to flexions; and to older, and probably at times younger, slates having been caught up in their folds. The splitting up then of the Sach conglomerate into two arms seems to be only a reproduction of the conditions of the Hulh (Hul) section, where a great thickness of silurian slaty rocks have, in the manner explained in Part III, been inserted between the Sao and Bagai outcrop of the conglomerate.

The Phinphar outcrop of the conglomerate apparently curves round to the north-east, for Dr. Hutchison tells me that he found numerous boulders of this rock as well as limestone near the village of Banu up the Hanan nála, which runs into the Chandra Bhága at Kilar.

Dr. Hutchison is also of opinion that the Sugwas and Sulgraon outcrops are continuous (which was also the view taken by Mr. Lydekker), and that the outcrops observed by him (Dr. Hutchison) on both sides of the Chara Pass runs into it.

The Salgraon outcrop apparently curves round and runs along the northern side of the Kali Cho, for Dr. Hutchison observed numerous boulders of it in the stream flowing down from the Cheroh snowy cone into the Chandra Bhága at Triloknáth; whilst we saw none in the bed of the stream at Luindi on the southern side of that mountain.

The slates associated with the upper silurian conglomerate in the parts of Pángi embraced by Dr. Hutchison's paper are probably middle silurians considerably altered by the proximity of granite.

It is interesting to note that, as in the Simla area, the conglomerates are rarely far separated from limestones; those immediately in contact with them presenting points of resemblance to the Blaini rock.

I have not coloured the limestone outcrops noted by Dr. Hutchison on my map, because the doubt remains whether they are of upper silurian age, or whether they also embrace some of the carboniferous limestones. This doubt was also felt by Mr. Lydekker with reference to the limestones observed by him in the region embraced by Dr. Hutchison's paper.

In the typical Simla area a thick band of infra-Krol (carboniferous) slates intervene between the Blaini (upper silurian) limestones and the carbo-triassic (Krol) series; but these carbonaceous slates seem to be sometimes absent in the Chamba area.

In view of this difficulty, and in the absence of fossils, I have thought it best not to give the limestones of Pángi, noted by Dr. Hutchison, a distinctive colour on my map.

Conclusion.

The result of the tours detailed in the preceding pages has been to confirm me in the view expressed in my paper on the Geology of Dalhousie, that the trap of the Dalhousie-Chamba area is of infra carboniferous age, and that in this region it comes in between the carbo-triassic and the silurian series.

To the north-west of Dihur, where the carbo-triassic limestones have either thinned out, or, more probably, have been squeezed out in the course of the plications in which the Chamba area has been involved, the trap is in contact with the upper silurian conglomerate along both margins; whilst at Dihur, and in the Bailaum-Sao direction, it comes in between the carbo-triassic series and the conglomerate.

The trap dies out between Dihur and Bailaum, but it will be seen on referring to the map that the disappearance of the trap coincides with a very sharp bend in the strike of the strata. The trap when it disappears in the neighbourhood of Dihur is in contact with the northern boundary of the carbo-triassic series, whilst when it re-appears it is in contact with the southern boundary of that series. On the supposition that the trap intervenes between the upper silurian conglomerates and the carbo-triassic series, this may be accounted for by the flexions in which

these rocks have been involved. Moreover, the deposition of the lava streams of the infra-carboniferous volcanoes may have been limited towards the west in the Dihur area, and towards the east in the Bailaum and Sao area. Furthermore, it is evident that the plications in which the Chamba rocks have been involved resulted in faults, for the upper silurian conglomerates, which are in contact with the northern boundary of the carbo-triassic series at Dhar and Kalel, have been removed to a distance from that boundary in the Hulh and Sao sections, what appear to be silurian rocks lower in the series than the Simla slates coming in between them.

The northern boundary of the carbo-triassic series in the Bailaum-Sao area, therefore, being evidently a faulted one, the non-appearance of the trap along the northern boundary of the carbo-triassic limestones in that area need occasion no surprise.

The fact that the trap dies out between Dihur and the neighbourhood of Bailaum may be due either to faulting or to the fact that the Dihur and the Bailaum flows were connected with different volcanic vents, and the lava flows did not extend into the area between Dihur and Bailaum. This last explanation is, I think, the true one, and it is the one which I have adopted in Part III of this paper.

Mr. Lydekker at page 241 of his memoir on Kashmir remarks that "It cannot be taken as certain that all the conglomerates of the Kashmir valley correspond to the Blaini conglomerate, since in the Pir-Panjál range the conglomerates appear to occur in the middle of the slate series, and are never even when the traps are absent in direct contact with the Zanskár rock."

I do not venture to offer any opinion about the Pir-Panjál rocks, but the result of my explorations detailed in this paper show that where plications and faults are abundant, some sections are apt to be misleading. A traveller journeying northwards from Hulh through Chanju would encounter a great thickness of silurian rocks on either side of the conglomerate; whilst another journeying northwards along a parallel line through Kalel would find the conglomerate in junction with the carbo-triassic series on both sides of the outcrop of the latter.

I have examined under the microscope a slice of the fine-grained sandstone which intervenes between the conglomerate at Chanju and the carbo-triassic series at Hulh. It is a highly indurated rock composed of grains of quartz and felspar with strips of muscovite in it here and there. The whole of the interstitial mud has been converted into mica, apparently paragonite. Under the microscope the sandstone has an ancient aspect, and its appearance confirms my impression that it is a silurian rock that occurs lower down in the series than the Simla slates.

PART II.

THE MICROSCOPIC STRUCTURE OF THE TRAPS DESCRIBED IN PART I.

I have already described in the preceding pages the way in which trap crops out along two distinct lines, one to the north, and the other to the south, of the carbo-triassic series. In the following pages I purpose giving the results of the

examination of thin slices of these traps under the microscope, and then to compare the two outcrops with each other, and with that in the Dalhousie area.[1]

I shall begin first with the trap to the north of the carbo-triassic series.

Ridge above Bhándal—Altered Basalts.

No. 1.—A greenish-grey rock mottled with epidote. Sp. G. 2·86.

M.—The groundmass consists of triclinic felspar crystals radiating in all directions. Augite was originally abundant, but a considerable portion of it has been converted into epidote *in situ*. The augite is traversed by cracks stopped with epidote and viridite.

The slice contains much magnetite, or ilmenite, and some hæmatite and viridite.

The rock is an altered basalt approximating to a diabase. No glassy base can be made out and the slice contains no liquid cavities.

No. 2.—A greenish grey compact rock rather mottled in its appearance. Sp G. 2·94.

M.—Epidote abounds in this slice, but no augite can be identified with certainty. Viridite is abundant. The felspar is in rather large crystals, many of which are visibly triclinic.

The slice contains a small amygdaloidal cavity stopped with viridite, calcite, quartz and a white zeolite. The quartz contains a few liquid cavities with movable bubbles.

I think this specimen belongs to the same class as the last, but it is a highly altered rock.

Andesites.

No. 3.—A greenish-grey compact rock. Two amygdules are visible in the hand specimen, composed of a white zeolite and a little epidote. Sp. G. 2·80.

No. 4.—A greenish-grey compact rock, little red specks being visible in it, here and there, due to the peroxidation of the iron. This sample is very like a typical specimen of the Mandi and Dalhousie traps. Sp. G. 2·82.

M.—Most of the felspar is visibly triclinic and it is grouped in the usual stellate manner. Crystals of epidote are here and there to be seen, and there is a considerable amount of viridite in irregular lake-like spaces. A green dichroic mineral, which appears to be hornblende, is present in minute prisms, fringing, or more or less connected with viridite.

Extinction takes place at an angle from the axis of the prism which agrees with the angle of extinction for hornblende.

There is a good deal of ilmenite, and possibly magnetite, present in the slice, besides some leucoxene, hæmatite and ferrite. The red spots seen on the hand specimens are due to the two latter secondary products.

These specimens, which appear to belong to the andesite group, are particularly interesting, as they seem to me to exhibit in its first stages those metamorphic changes, which have, I think, converted some of the igneous rocks of the Satlej area into hornblende schists.

[1] Described in Records, XV, p 34.

No liquid cavities are present in slices 3 and 4.

No. 5.—A greenish-grey compact rock. It fuses under the blowpipe to a dark, almost black, magnetic bead. Sp. G. 2·79.

M.—This is a highly felspathic variety; it consists of congeries of felspar crystals, many of which are visibly triclinic, imbedded in a glassy base. A pale almost colourless viridite is rather abundant. Very little epidote is present. The slice contains a considerable amount of magnetite and a red product of its alteration. This specimen is, I think, a transitional variety between the andesites and felsites.

Felsites.

Nos. 6 and 7.—Greenish-grey compact rocks. Sp. G. 2·96 and 2·80. Both fuse under the blowpipe to a dark, almost black, magnetic bead.

M.—No. 6 consists of epidote in a colourless glassy-looking base, which remains dark when revolved between crossed nicols.

No. 7 has none of the microscopic characters of serpentine, and it unquestionably is not that substance, but nevertheless under the microscope it looks more like serpentine than anything with which I can compare it. In ordinary transmitted light it appears to be composed of granular matter imbedded in a colourless, or nearly colourless, base. Between crossed nicols the granular matter is seen to be isotropic, and the field remains dark between crossed nicols, relieved by stripes and irregular patches of the doubly refractive matter which polarise with a yellow tint.

A little epidote and calcite are to be seen here and there; whilst the slice is dappled with patches of a substance, white in reflected, and opaque in transmitted light. Neither specimen contains any trace of a basaltic mineral.

No. 8.—The weathered surface has a slaty aspect, but when a lens is used, unweathered portions present a mottled felspathic appearance. In colour the rock is a pale greenish-grey. Sp. G. 2·81.

M.—The groundmass consists of a glass of very pale yellow-ochre colour in transmitted light. In this there are little patches and strings of colourless granular matter, crystalline in aspect, which remain dark when revolved under crossed nicols. Clear lacunæ of the yellow glass are seen here and there: they have invariably a border of the granular matter, and patches of this product of divitrification penetrate into and are dappled over the lacunæ.

Under crossed nicols the pale yellow base breaks up into a black and white, mottled crypto-crystalline mass, whilst here and there portions polarise with a yellow tint.

The arrangement of the whole, both with and without polarised light, is highly suggestive of fluxion structure.

A few specks of red ferrite are visible in the slice.

No. 9.—A compact rock of reddish brown-colour mottled with green. Sp. G. 2·80.

M.—The base is crypto-crystalline like the last specimen. In this blebs of quartz are sparsely distributed, and there is a considerable amount of epidote. Some of the latter looks much like augite in process of conversion into epidote

There are cracks and veins in the slice filled with quartz, and some of these cracks penetrate the epidote.

The quartz contains liquid cavities with movable bubbles, but they are very minute and require high powers to be visible.

The magnetite has almost wholly been converted into an opaque red ferrite and to this change in the oxidation of the iron the red colour of the rock is due, the yellowish-green patches being due to the presence of epidote.

Specimens 6 to 9 must, I think, be as classed as felsites.

Basalt Porphyry.

Six hand specimens and seven thin slices of the porphyritic variety of the trap found on the ridge above Bhandal have been examined.

The porphyrite is an extremely tough rock and breaks with great difficulty, even when a heavy hammer is used. The matrix is perfectly compact, and it is generally of a dark bluish-grey colour, though in some specimens it is greenish-grey.

The specific gravity of the basalt porphyries ranges from 2·76 to 3·01, the average specific gravity being 2·89.

Under the microscope, the groundmass, in most of the specimens, is seen to be of basaltic structure, and consists of minute prisms, and crystallites of felspar, set in a matrix of fine granular matter; whilst in others this granular matter is comparatively sparse, and the groundmass approximates, in character, more to an andesite or trachyte, and consists of a net work of minute, but for the most part, imperfectly formed crystals of felspar.

Fluxion structure is more or less observable in all the specimens. In some the groundmass passes here and there into a micro-felsitic substance.

Magnetite is abundant in all the slices, being present in micro-grains of irregular shape. Ilmenite also is, or has probably been, present, as the slice is dappled with an opaque substance resembling leucoxene.

Augite in granules appear to be sparsely present in a few specimens.

The great majority of the porphyritic crystals, and a large number of the micro-prisms of felspar, are visibly triclinic. The former are much corroded, cracked and broken, whilst portions of the groundmass penetrate into their substance in the form of tongues. Some of those large plagioclase fragments are much bent, the planes of twinning being bent with the prism; whilst one crystal is broken into fragments which have been floated to some little distance from each other. These porphyritic crystals clearly belong to the first epoch of consolidation.

The slices contain rather large crystals of augite, but most of it is much altered, being converted into a brownish-yellow substance, or into epidote.

One of the slices, the groundmass of which is of unusually small grain, abounds in what appear to have been vesicular cavities. They are nearly all flattened and drawn out into irregular-shaped lacunæ. They are lined round the edge with granular epidote and stopped with epidote, and a serpentinous-looking substance, of the palest yellow tint in transmitted light.

Some of the large felspars contain cavities filled with viridite and epidote, which probably represent olivine or augite crystals : others contain small patches of calcite and viridite, the evident products of decomposition.

A few cavities contain secondary quartz and a zeolite.

In one of the slices, the magnetite, which here and there is crystallized in a regular manner, exhibits a tendency to assume semi-circular forms. One of these figures resembles the wheel of a cart cut in half, there being a thick semi-circular ring of uniform width with spokes radiating to it from a sort of nave.

I have not detected any liquid cavities in the secondary quartz or in the felspar.

This variety of the trap should, I think, be called a basalt porphyry.

Ridge above Tiloga. Volcanic tuffs.

No. 17.—A greenish-grey compact rock .	Sp. G. 2·67
„ 18.—A grey compact rock . . .	Sp. G. 2·82
„ 19.—A dark greenish-grey rock . .	Sp. G. 2·93
„ 20.—A grey compact rock . . .	Sp. G. 2·87
„ 21.—A greenish-grey compact rock .	Sp. G. 2·70

In No. 17 the weathered surface presents a fine-grained granular appearance, which strongly suggests the idea that the rock is a consolidated ash. In No. 18 the surface is so overgrown with lichen that nothing can be made out; but in No. 19 the granular character is somewhat doubtfully discernible. In Nos. 20 and 21, the weathered surface gives indications of a laminated arrangement of the materials. Most of the specimens are more or less finely vesicular, or have empty interspaces here and there between the grains.

M.—The majority of the slices are distinctly vesicular, a structure which is very characteristic of an ash,[1] but, with the exception of No. 20, none of the slices give any indication of fragmentary structure under the microscope. In the last-mentioned slice, much of it is seen between crossed nicols to be fibrous in patches, the fibres in one patch running in a different direction to those of neighbouring patches,—an arrangement which imparts a fragmentary appearance to the whole. In No. 21 the remains of a crumpled lamination are distinctly visible, the old lamination being represented by irregular lines of viridite.

No augite, felspar, or other original mineral of the lava, except magnetite, is visible in any of the slices; but epidote, green mica, and patches of calcite are generally distributed throughout them.

A dull quartz finds a place more or less in all the slices ; it is scattered about in minute flecks, or in micro-grains, which exhibit a strong tendency to cluster together, and form, with granular viridite, spots dotted over some of the slices. Magnetite also shows a tendency to form borders round those spots, and here it is probably a secondary product.

Irregular veins traverse some of the slices, and they are stopped with quartz, magnetite, and granular viridite. Some amygdaloidal-looking cavities are filled with calcite, and quartz, in micro grains.

[1] See Dr. Sorby in Q. J. G. S., Vol. XXXVI, p. 55.

Viridite forms a more or less prominent object in all the slices. There are no porphyritic crystals; the groundmass contains neither microlith nor crystallite and presents no characteristic structure.

The Tiloga specimens are all, I think, intensely altered volcanic tuffs. Nos. 17 and 18 might conceivably be highly altered vesicular lavas, in which case one would have to attribute the distinctly fine-grained granular surface to the effects of weathering on a very fine-grained vesicular mass, but this supposition is not a probable one. No. 19 may possibly be a highly altered felsite. "Finely bedded ash, when *highly altered,* is undistinguishable in microscopic structure from an undoubted felstone-lava;"[1] but in this case the high specific gravity of No. 19 is opposed to the view that it is an altered felsite. On the whole, taking into consideration the granular weathered surface of No. 17, the distinctly laminated structure of No. 21, and the general features of these specimens, I have with some doubt and hesitation come to the conclusion that Nos. 17 to 21 are *highly altered* volcanic tuffs.

Considering the age of these rocks it is not surprising that ash of so fine a grain should have been so highly altered.

The Bailaum-Hulh (Hul) outcrop. Altered volcanic ash.

The samples (1 to 21) above described are from the outcrop of the trap to the *north* of the carbo-triassic series running from near Dihur (Duire) in a north-westerly direction towards Badrawár. The following specimens were taken from the outcrop which occurs to the *south* of the carbo-triassic series between Bailaum and Hulh.

Nos. 22 and 23.—Greenish-grey compact rocks from Bholu, under the Bundhar Trigonometrical Survey station. The outcrop here is only about 100 feet in thickness. The Sp. G. of No. 22 is 2·84 and of No. 23, 2·88. No. 22 is somewhat fissile, and minute specks of mica are visible in it here and there. On the cut surface it has a streaky appearance. One of the surfaces of No. 23, which is perfectly flat, is distinctly granular.

M.—The groundmass of No. 22 is crypto-crystalline; no definite crystals of felspar are anywhere discernible, granules or fragments of what appears to be augite, are scattared about in it; the most prominent feature, however, is the presence of what I take to be hornblende in minute thin prisms, fibres, and irregular masses intermingled with mica. The hornblende in transmitted light is of the palest brown-green colour, and is not at all dichroic. Extinction takes place at from 3 to 20 degrees from the axis of the prisms. The prisms and fibres, generally, but not always, run in the same general direction, whilst the mica always does so. The slice contains several empty vesicular cavities.

No. 23 is much the same sort of rock as the last; the hornblende, however, is absent, and a mica ranging from a pale brown-green to a reddish-greenish-brown takes its place. This mica is abundant.

Crystals of felspar, most of which are visibly triclinic, are very abundant in this slice; their external outlines are highly irregular, and never exhibit straight lines.

[1] J. Clifton Ward, Q. J. G. S., Vol. XXXI, p. 405.

The slice contains a few patches of hæmatite. There are some vesicular cavities, some of which are stopped with calcite; calcite also occurs in minute granules throughout the slice.

Some of the felspars contain a few extremely minute cavities with movable bubbles.

Both specimens are, I think, intensely altered ashes.

Hulh. Hornblende andesites.

The following specimens were taken below the village of Hulh, in the valley of that name, from the same horizon as Nos. 22 and 23, but some miles to the south-east of Bholu.

No. 24.—A fine-grained pale greenish-grey rock. With a pocket lens it is seen to be sub-crystalline. Under the blowpipe it fuses to a very dark magnetic bead. Sp. G. 2·88.

M.—This is quite a typical lava: it is composed of an intimate mixture of triclinic felspar, in prisms radiating in all directions, and hornblende. The latter is in prisms fringed at the ends with microlites of the same mineral. The hornblende is of the palest conceivable green tint and exhibits no dichroism; here and there, however, the prismatic cleavage planes intersect at the angle characteristic of hornblende; extinction also agrees with that of this mineral.

No augite can be identified, but epidote, colourless in transmitted light, and which does not exhibit dichroism, is rather abundant. A little secondary calcite is also present. No magnetite or ilmenite is to be seen, but the slice is dappled with a granular opaque substance, white in reflected light, which seems allied to leucoxene.

A glassy base of very pale yellowish-green colour is visible here and there. The felspar contains nests of microlites which may possibly be apatite, but I think they are more probably colourless hornblende like those fringing the ends of the hornblende prisms. Their action on polarised light is swamped in that of the felspar.

The rock is evidently one that has suffered a large amount of alteration.

No. 25.—A greenish-grey compact rock much mottled with epidote and containing zeolitic amygdules here and there. Sp. G. 2·98.

No. 26.—A bluish-grey compact rock with specks of white zeolite showing in it. Sp. G. 2·89.

No. 27.—A bluish-grey compact rock. Sp. G. 2·91.

M.—These are all highly altered rocks. The ground mass is felspathic, passing, in No. 26, here and there into quartz. It contains mottled masses and fine acicular prisms of hornblende. The hornblende is of green colour and is feebly dichroic in No. 25, but is colourless and non-dichroic in the other slices.

Epidote is a prominent feature in No. 25, and it is more or less abundant in the other slices also. A mica of greenish-yellow colour in transmitted light is present in No. 26. Square and triangular sections of magnetite occur in No 25.

All these slices (Nos. 25 to 27) contain amygdules composed of zeolites, quartz, calcite, epidote, and mica. The zeolites are full of liquid cavities with movable bubbles.

Conclusion.

Some of the specimens described in the preceding pages (Part II) very much resemble, in macroscopic appearance, typical specimens of the Dalhousie and Mandi altered basalts; but the result of the microscopic examination of the whole is to show that, in the region north of Dalhousie, the traps have changed considerably in type; they present more variety, too, than those south of Dalhousie.

In the ridge north of Bhándal basalt porphyries become prominent and afford an additional link between the volcanic rocks of Chamba and those of Kashmir, where similar porphyritic traps are not uncommon.[1]

I have termed the porphyritic rocks above described basalt porphyry, because in specific gravity they range as high as 3·01, and their average is 2·89; and because the groundmass of most of them is basaltic in structure. In some specimens, however, the groundmass approximates in character to that of an andesite or trachyte; but the felspars belong to the triclinic system, and the rock, therefore, is clearly not allied to the trachytes.

No olivine has been found in any of the specimens examined; but considering the age of these rocks and the extent to which they have undergone alteration, I do not, for the purposes of classification, attach much importance to this fact. Olivine is an unstable mineral and one of the first to succumb to aqueous or hydro-thermal agencies; the rock contains secondary products that commonly result from the decomposition of olivine; whilst the high specific gravity of the rock indicates that it belongs to the basic class.

Of the unporphyritic and compact traps described in the preceding pages, the microscope shows that Nos. 1 and 2 are altered basalts approximating to diabase. These specimens probably represent dykes of volcanic matter, injected, at some pressure, into rents in the accumulated lava, rather than surface flows. The rest of the specimens of compact trap examined exhibit a considerable change of type as compared with the volcanic rocks south of Dalhousie. As a whole they are more felspathic in character, so much so that I have classed Nos. 6 to 9 as felsites. Hornblende makes its appearance, and in some specimens it forms, with triclinic felspar, the predominating mineral. I have classed these as andesites and hornblende andesites. Some of these rocks, as for instance No. 24, are quite typical lavas.

Another interesting feature brought out by the examination of the specimens described in Part II of this paper is, that there seems reason to regard those from Tiloga, near the south-east termination of the northern outcrop, and those from Bholu, near the north-west commencement of the southern outcrop, as altered ashes.

This would seem to favour the view that the outcrop to the north of the carbo-triassic series belongs to an eruption distinct from that which supplied the lava to the south of that series; ashes taking the place of lava along the skirts of the pre-carbo-triassic volcanoes.

[1] Lydekker's Káshmir, pp. 221 and 218.

If the Tiloga and Bholu beds are, as I take them to be, altered tuffs, this conclusion will help us to understand doubtful rocks in other localities and confirm the inference already arrived at regarding some Kashmir traps.[1] This determination, moreover, supports the view advanced by Mr. Lydekker in his Memoir on Kashmir,[2] that the volcanic rocks of the North-Western Himalayas were derived from true volcanoes, and do not belong to the type of "fissure eruptions."

The supposed absence of ash-beds, I apprehend, was one of the reasons which prevented some early observers from recognizing the volcanic character of the traps of the North-Western Himalayas and Kashmir; but considering the age of these beds, it is not surprising that fine-grained tuffs have been altered almost out of recognition.

Another point in the microscopic examination of the specimens described in the preceding pages, which has interested me, is the connecting link which the hornblende andesites, and the altered tuffs, seem to supply between the palæozoic volcanic products and the hornblende rocks, and hornblende schists, of the Satlej valley.

In the andesite lavas and tuffs described in these pages, we see the augitic element, so prominent in the lavas south of Dalhousie, and in those of Mandi, disappearing, and hornblende taking its place. Quartz, probably, in this case, a product of the decomposition of felspar, begins to appear; the tuff No. 21 has a finely laminated structure favourable to its conversion into a schist; and I think we see in some of these hornblende andesites, and in the tuffs, the beginnings of metamorphic changes which were probably carried further in the Satlej area, the seat of extreme metamorphic action, and resulted in the conversion of similar volcanic products into the hornblende rocks and hornblende schists found there.

I need say no more on this subject here, as the microscopic structure of some of the Satlej rocks will form the subject of a future paper. I need only add that I do not intend to imply, by the above remarks, that *all* the hornblende bearing rocks of the Satlej valley are volcanic products. Some of the Satlej valley rocks are doubtless diorites and cannot therefore be supposed to have actually flowed out on the surface as lava, though they were probably connected with volcanic action.

PART III.

GENERAL OBSERVATIONS ON THE STRATIGRAPHY AND PETROLOGY OF THE DALHOUSIE AREA.

Owing to my approaching departure from India, this will probably be the last paper on the geology of the Dalhousie region that I shall have an opportunity of writing for the Records; it may be well, therefore, to state how far the views expressed in my first communications have been modified by further experience and observation in the field, and by the detailed study of thin slices of rocks under the microscope.

[1] Memoirs, Geol Surv., Vol. XXII, pp. 218, 221.

[2] *Ibid*, p. 222.

In my first paper I gave expression to the opinion that the limestone-beds south of Dainkund were of carboniferous age, and that they formed a normal sequence from the altered basalts upwards. I now think that these beds, as suggested by Mr. Lydekker in his interesting memoir on "The Geology of the Kashmir and Chamba Territories," have been thrown into a compressed fold.

The hypothesis of a compressed synclinal flexure accounts better than the explanation previously adopted for the fact noted in my first paper, that notwithstanding the typical development of black infra-Krol rocks along the eastern border of the outcrop, some dark slaty rocks occur at one point on its western boundary.

This hypothesis, moreover, has the advantage of bringing the stratigraphy of the limestone series south of Dainkund into harmony with that of the limestone outcrop north of that ridge. In both, the trap (see section B.) occurs along the western margin of the limestones, and is absent on the eastern border. In both cases the explanation now offered is the same; namely, that a compressed fold in the rocks (the limestones being thrown into a syncline) resulted in a fault, the trap being cut off by the fault.

It is to be noted that the dark carbonaceous infra-Krol rocks visible in the limestone outcrop south of Dainkund are absent from the outcrop north of the Rávi, but this may probably be owing to the latter having been laid down in deeper water further from the shore.

I am unable to accept some other suggestions which Mr. Lydekker has made in his memoir. Mr. Lydekker never visited the Chamba area, and his suggestions were based principally on observations recorded in my papers published up to that date, and I think it will suffice to state briefly in the following pages the conclusions at which I have finally arrived.

When I wrote my first paper on the geology of Dalhousie I had not studied thin slices of the Dainkund granite under the microscope,[1] and I had to make the best I could of the facts known up to that date I had no wish to strain or go beyond my facts. I had evidence of intrusion, on the one hand, and of distinct foliation, on the other, and it was necessary that any explanation I had to offer should harmonize these opposing facts. "The explanation that satisfies my mind most," I wrote (Records, XV, p. 47), "is that the intense metamorphism of the 'central gneiss' has been principally produced by granitic intrusion at a great depth below the surface; and that the perfectly granitic portion is the intrusive granite itself." After discussing instances of volcanoes bursting through gneissic beds, I added that I could "see no reason why what took place near the surface at Auvergne may not have taken place in other localities at a greater depth below the surface;" and added further on, "I can therefore readily imagine that under the conditions described a blending together of the granite and the gneiss would result, and that the latter would, for some distance from its contact with the granite, partake of its mineral character."

This view has been accepted and adopted by Mr. Lydekker in his memoir. Now however that the microscope has thrown so much new light on the subject,

[1] Owing to the pressure of official work I should have been obliged to postpone my first paper for a very long time had I waited to complete a microscopic study of all the Dalhousie rocks before writing it.

I am unable to confine myself to a view, which, though it went as far as my facts would carry me in 1881, seems, in view of the new facts brought to light, to only express half the truth.

The microscope has shown that not only the gneissose granite of the Dhuladhár, but the foliated beds in the Rávi valley and the outer band at Dalhousie, give evidence of having been, at one stage in their history, reduced to a plastic condition by aqueo-igneous fusion, and exhibit fluxion structure, namely, evidence of motion. Moreover, the numerous specimens taken from various distant points in the localities indicated above, however much they may differ from each other in macroscopic aspect, present under the microscope absolutely no difference in composition or structure.

There is thus a cogent argument for concluding that if portions of the crystalline rocks of the Dalhousie area are of eruptive origin, the whole of them are granites.

It would indeed be strange if metamorphic schists and gneiss of archæan age so exactly resembled comparitively modern eruptive granite that the microscope could detect no difference whatever between them either in composition or internal structure. This would be all the more remarkable, as the Dalhousie rocks do not, by any means, belong to a common type of rock, but, on the contrary, have special peculiarities of their own. When we see these special peculiarities permeate all the granitoid rocks in the same locality, the most natural inference to form regarding them is that they have had a common origin.

The Dainkund gneissose granite has been shown to have exercised a metamorphosing action on the rocks in contact with it; veins of it intrude into the slates and silicious rocks on both margins;[1] the gneissose granite contains veins similar to those caused by shrinkage on cooling in granites of admittedly eruptive origin; whilst it also contains inclusions of slates and schists imbedded in it, which are without reasonable doubt true slates and schists, and not the products of segregation; and these inclusions are met with not only along the line of contact with the sedimentary beds, but at least half a mile away from them.

A granitic mass that presents the above features must, I think, be considered an eruptive rock. The mere fact, taken alone, that portions of this mass display a tendency, more or less pronounced, to assume a parallelism in the arrangement of its crystals, is not, in itself, sufficient to support the theory that the foliated portions are of metamorphic origin, or to support the further assumption that has been made, that these portions are of pre-cambrian age.

The presence of parallelism of structure in some trachytes was demonstrated long ago by Naumann and Scrope, whilst the existence of gneissose granite, and the eruptive character of such foliated rocks as leptynite (granulite), is now admitted by many leading geologists, and gneiss-granite or gneissose granite has become a recognized geological term.

"It was formerly considered," writes Bernhard von Cotta,[2] "that all gneiss was of metamorphic origin, but it has of late years been established beyond a

[1] I have observed, but not heretofore noted, one on the Chamba side of the Chuári Pass.

[2] English Edition by Lawrence; new Edition, p. 225.

doubt that many kinds of gneiss are irruptive, and some geologists have gone so far as to regard all gneiss as of igneous origin."

If trachyte, a rock that has flowed out on the surface of the earth's crust, has in some instances been known to assume a "striped" and foliated appearance, how much more may we not expect to find a parallelism of structure in acid rocks forced through the walls of a fault in a viscid and partially cooled state under conditions of great pressure and strain?

Naumann[1] refers, among other instances, to a trachytic lava observed by Hoffmann in a crater in the Island of Pantellaria, "which throughout has a foliated texture resembling gneiss, and occurs in beds that dip regularly outwards from the centre of the island; and he refers to the observations of Darwin to the effect that "a volcanic rock" in the Island of Ascension has "a perfect gneiss-like texture and structure, the alternate layers of the component parts being extremely fine, and extending parallel to the direction of the lava stream."

Another observation of Darwin alluded to by Naumann in his paper is so apposite to the case of the Dalhousie crystallines that it is worth quoting. "Darwin informs us," writes Naumann, "that in the Cordillera of Chili, great beds of red granite occur, which must be viewed as an eruptive rock; but that it nevertheless exhibits, in parts, a decidedly parallel structure."

If the existence of a gneissose granite in the Dalhousie, Satlej and Chor areas be admitted—and my microscopical investigations have led me to this conclusion in respect of the crystalline granitoid rocks of those areas—I see no reason why very similar rocks in other parts of the North-Western Himalayas heretofore called "central gneiss," and "granitoid gneiss" should not be written down as gneissose granite also, unless, and until, their original sedimentary origin and archæan age be proved.

For instance, the description by Mr. Wynne of the Hazára gneiss (quoted by Mr. Lydekker at p. 103 of his memoir); its completely crystalline porphyritic and granitoid character; its behaviour in relation to the schists that border it; its intrusion "in dykes and veins" into those schists along the margin of contact, so exactly resembles the Dainkund and Chor rocks that Mr. Wynne's description of the Hazára gneiss might be read as a graphic and perfect description of the Dainkund and Chor gneissose granite.

The conclusion that much, if not all, of what has been called "central gneiss" and "granitoid gneiss" is really an eruptive rock, removes many difficulties from the way of the Himalayan geologist. "Despite the wonders performed by flexure of strata in mountain regions," wrote Mr. Medlicott in his annual report for 1883,[2] "the structural features presented by this rock in certain cases were impossible of satisfactory explanation on the supposition of its being really stratified gneiss. The Chor mountain in the Simla region and the end of the Dhuladhár ridge at Dalhousie are instances."

Other examples of difficulties capable of removal may be culled from Mr. Lydekker's memoir on Kashmir. Lenticular or ellipsoidal masses of gneiss are

[1] On the probable eruptive origin of several kinds of gneiss and gneiss-granite. Q. J. G. S., Vol. IV, 1848.

[2] Records, XVII, p. 3.

described as occurring in the midst of the silurian slates (pp. 231, 255); the passage from the slates to the gneiss appears to be generally gradual and imperceptible (pp. 255, 258, and 260); but at p. 250 we are told that "the lower part of the system" (*viz.*, the Panjál, which Mr. Lydekker at p. 47 correlates with the silurian and cambrian (?) systems) "next the underlying gneiss, may apparently consist either of mica schists, or of little altered slates, which would seem to be difficult to distinguish from the higher Simla slates. Finally it appears that there is generally a gradual passage from the lower beds of the system into foliated, and then into granitoid gneiss, but that there are instances where the junction is somewhat sudden." Or, in other words, there is occasionally a sudden passage from comparatively unaltered slates, undistinguishable from beds supposed to be of middle silurian age, to a perfectly crystalline granitoid rock.

Sometimes the gneiss appears to come in above the upper silurian or lower carboniferous traps (p. 230); and at other times next the upper silurian conglomerates (p. 290). Some of the gneiss is considered to be of pre-cambrian age (pp. 235, 265); some to be metamorphosed beds of middle silurian age (p. 251); and some to be the altered equivalents of rocks higher than the Panjáls (p. 265), namely, of more recent age than the silurian system.

Mr. Lydekker does not indicate any mode of distinguishing between the eruptive granites and the granitoid metamorphic rocks on the one hand, or between the pre-cambrian, silurian and younger gneisses on the other.

Some of our leading geologists, who have given special attention to archæan rocks, would, I think, be indisposed to believe in the existence of thoroughly crystalline granitoid metamorphic rocks of such diverse ages as those stated above, in the same mountain region; and they would probably suggest the introduction of a number of faults to account for the erratic appearance of a thoroughly crystalline granitoid gneiss sometimes at the bottom, sometimes in the middle, sometimes at the top of the silurian series, and sometimes in younger beds; and to account for the juxtaposition of comparatively unaltered slates and crystalline rocks in the last stage of extreme metamorphism.

I do not understand that Mr. Lydekker has resorted to an elaborate system of faulting to explain the facts noted above, but on the contrary that he believes his metamorphic gneisses to belong to "more than one gelogical period" (p. 265).

For my own part, as I hold that there is sufficient evidence to justify the belief that the crystalline granitoid rocks of Dalhousie, of the Satlej valley, and of the Chor mountain, are eruptive granites, I would account for the cases noted above, and similar ones, by applying to them the explanation which has solved even greater difficulties in the Dalhousie and Chor areas.

If eruptions of gneissose granite on so grand a scale occurred along the Dhuladhár, the Chor, and in the Satlej valley region, it is only natural to expect that similar eruptions occurred in other parts of the North-Western Himalayas; and this expectation becomes almost a certainty when we find a crystalline granitoid rock undistinguishable from the gneissose granite of Dalhousie, and of the Chor, presenting itself in different horizons amongst the silurian and younger rocks. If the gneissose granite is really an eruptive rock, this is just what we

should expect to find; indeed, if it never cropped out except along the same horizon, there might be some ground for regarding it as a metamorphic rock. But when we find a crystalline granitoid rock preserving its identity of character over very extensive areas, and yet cropping out along widely different horizons in rocks "of more than one geological period," it seems to me that the grounds for claiming it as a metamorphic rock are slender indeed.

On the assumption that it is an eruptive rock the difficulties I have indicated above disappear. We no longer wonder with Mr. Lydekker why no case of the overlap of the "central gneiss" by the silurian series has ever been discovered (p. 302); and we at once understand why granitoid rocks are found along widely different horizons, and why, in some cases, there is an apparent transition from the sedimentary series to the crystalline rock, and why, at others, there is an abrupt passage from the latter to comparatively unaltered slates. Where the gneissose granite was erupted among lower silurian or cambrian (?) beds that had already been subjected to more or less regional metamorphism, and on which it would produce some contact metamorphism, an appearance of gradual transition would naturally be the result; where, on the other hand, the partially cooled gneissose granite was erupted along a fault and in contact with unaltered slates, the contact action would not be sufficiently intense, or extend far enough, to create an appearance of gradual transition, and the result would be, as at Dalhousie, a sudden passage from slates to gneissose granite.

I now pass on to offer some remarks in explanation of the diagrammatic sections attached to this paper (Plate).

Section I has been taken (see map attached to this paper) through Dainkund and Tisa to the Sách pass.

The tertiary series does not come within the scope of this paper, and the stratigraphy of the trap and the carbo-triassic series has already been discussed in the preceding pages. I pass on to the silurian series. Along the section under consideration, the silurian beds, on both sides of Dainkund, are in normal sequence. On the north-east of Dainkund we have the upper silurian conglomerates followed by typical Simla slates which pass into fine-grained silicious schistose beds. On the south-west of Dainkund, we have slates followed by fine-grained silicious schistose beds passing into mica schists. The silurian beds were thrown by lateral pressure into folds, as indicated by the dotted lines, and squeezed together until a fault was produced at Dainkund, and another further to the south-west, and a uniform dip in one direction was given to the beds. The gneissose granite rose along the line of fracture at Dainkund, and the "outer band" also forced its way through the more westerly fault between the carbo-triassic and the lower silurian beds. The upper silurian conglomerates, which to the north-east of Dainkund were thrown into a compressed isocline, were to the south-west of Dainkund squeezed out in the flexures in which the silurian beds were involved. To the north-east of the river Rávi, the upper silurian conglomerate has been thrown into compressed isoclines, the carbo-triassic limestones being caught up in a synclinal fold between the two isoclinal outcrops of the conglomerate. A synclinal flexure brings out the silurian beds after the conglomerates. The Simla slates have disappeared in this section, their place next the conglomerates

below Tikri[1] being taken by micaceous schistose rocks that crumble to a whitish soapy powder, indicative doubtless of the presence of a hydro-mica. The slates here may either have been more highly metamorphosed than those at Dalhousie, or they may have been squeezed out by local flexure and faulting.

Continuing from Tikri along section A in a north-easterly direction the soapy schistose rocks are followed[2] by fine-grained quartz schists, mica schists, and slaty mica schists occasionally passing locally into micaceous slates, and these rocks continue to near the top of the Sách pass.

A south-westerly dip is set up in the outcrop of the conglomerates on the northern side of the limestones, and it becomes pronounced at the stream under Tikri; beyond this the dip rapidly flattens and becomes wavy until the top of the Sách pass is neared, when a high south-east dip is resumed. This rapidly becomes perpendicular, and ultimately, on the north-east side of the pass, the conglomerates dip under older silurian beds.

Section II, through Dainkund, Hulh, and Chánju, differs in some important particulars from section A. As described in Part I of this paper, a band of trap crops out along the south-western border of the carbo-triassic limestones, and the latter are followed by silurian beds. In both these respects, if we leave the outer band of gneissose granite out of consideration, the section north-east of the Rávi agrees with that south-west of Dainkund, and another fault must be brought in to explain the contiguity of the carbo-triassic limestones with silurian beds somewhat low in the series, and the disappearance of the trap and conglomerates. A glance at section B will, I think, show that the relations of the several series to each other are not to be explained without putting a fault on the north-east border of the limestones. From the limestones down to the gneissose granite the several series are in normal sequence; the carbo-triassics are followed by infra-carboniferous trap; then comes the upper silurian conglomerate which, in its turn, is succeeded by Simla-slates and then silurian beds lower in the series. A synclinal fold would bring up the trap and the conglomerates again to the north-east of the limestones, as in section A, but the flexure having resulted in a fault, the trap and the conglomerates have disappeared.

This section is, I think, an instructive one, and will help to remove difficulties in other localities.

In the Pir Panjál range the conglomerates occur in the middle of the slates (Memoir, p 241), and Mr. Lydekker, in view of this fact, thought that "it cannot be taken as certain that all the conglomerates of the Káshmir valley correspond to the Blaini conglomerate." And again at p. 249 the author writes, "they seem further to indicate that the Blaini conglomerate of the Simla district may either be strongly developed at the top of the series, or that it may occur less strongly developed among the slates themselves." And again at p. 248, "It is noteworthy that these rocks" [the supra-Kuling series] "are not immediately underlain by the Blaini conglomerate, showing the inconstancy of the petrological characters of that member in these districts."

This apparent inconstancy, however, is, I apprehend, to be put down to the countless plications in which the Himalayan rocks have been involved; a glance

[1] Records, XVI, 39. [2] Records, XIV, 307.

at the map attached to this paper will show that the conglomerate, which south of Himgiri (Himgir) is in contact with the carbo-triassic (supra-Kuling) series, is gradually removed to a distance of over 6 miles from it in the Chánju section by the interposition of silurian beds lower in the series.

The dip of the carbo-triassic limestones in the Hulh section (section II) is north-east-by-north. The dip of the silurians which succeed them is vertical, but somewhat curved when the dip can be traced for any distance down the mountain side. A north-east dip afterwards sets in which becomes south-west along the crest of the ridge. It wavers from north-east to south-west more than once, and at one place is high to south, but under Chánju it settles down to south-south-west.

A section drawn through Dihur (Duire) and Himgiri (see map) would differ somewhat from those already described, for the trap here crops out on the north-eastern border of the carbo-triassic series instead of as in the section through Hulh, on the south-western border.

A study of the Hulh and Dihur trap (see Part II of this paper) has led me to the conclusion that the dying out of the trap between Dihur and Bailaum (section A through Dainkund and Tisa) is owing to the original limitation in the area of deposition.

On a first inspection of the Bhándal-Dihur area I suggested (Records, XVI, 41) that the fact that "the trap does not occur between the carbo-triassic series and the upper-silurian conglomerate, on both sides of the limestone outcrop, may I think be explained by the hypothesis of a fault between the limestones and the southern outcrop of the conglomerate:" and I expressed the opinion "that we have in this section a crushed synclinal fold, with a fault along its axis, the compression of the folded strata having been great enough to produce a general conformity of dip."

I think, now that I have reviewed the stratigraphy of neighbouring sections, that there is no need to call in the aid of a fault to solve the problem presented to us, and that it may be satisfactorily explained without one. Section V (Plate) represents a section drawn through Dihur in the direction of Himgiri, and IV and III sections drawn parallel to V a little more to the north-west. The folding of the strata in sections III, IV, and V is the same as that in section I. The explanation in all is that offered in my paper quoted above; namely, that the local strata have been thrown into a "crushed synclinal fold." On both sides of the limestones the conglomerates have been bent into isoclines, and the limestones are caught up between them and bent into a crushed syncline.

In I the trap is absent, this section being beyond the area of deposition. From the predominance of limestones, and the absence of the carbonaceous element here, it seems not improbable that the sea was comparatively deep in this locality at the end of the silurian period when the volcanoes were in an active state.

Section V represents the tail end of the volcanic deposition. The volcanic beds are thick on the north-east side of the limestone outcrop, and they thin out to the south-west.

In section IV we are further within the area of volcanic eruption, but we are getting nearer the bottom of the synclinal fold that is concerned with the upper-

silurian conglomerates, and consequently the limestone outcrop (a crushed syncline) is getting comparatively shallow.

At III we have arrived at a further stage; the limestones have been squeezed out of the section; the trap is doubled up upon itself, and is in contact with the conglomerate on both sides.

In sections I and II I have represented the silurian beds between the outcrop of the carbo-triassic beds north of the Rávi and Dainkund as forming a normal sequence, whereas in Part I of this paper I have suggested that in the Siul river section[1] "the Simla slates are folded up with older silurian beds in compressed isoclinal flexures." I may as well point out in passing that there is no confusion or contradiction in these statements. A comparison of the diagrammatical section I with section II will show that even along the same line of strike local details change rapidly within the distances of a few miles. Along section II the silurians in the valley of the Rávi appear to have escaped complicated flexions, whereas in the valley of the Siul, in the same strike, they appear to me to give evidence of having been involved in them.

Indeed the area near the junction of the Siul and the Rávi appears to have been a region of special strain. Lower-silurian beds (decided mica schists) extend from the stream between Tipri and Seru (Sairu) to the outer band of gneissose granite; whilst in the Bhale (Balai) section (see *ante*, Part I) the slates between the inner and outer bands of gneissose granite are very micaceous and at Bhale are decided mica schists. In section 1 through Dainkund the upper-silurian conglomerates have disappeared; whilst in the valley of the Rávi, opposite the mouth of Siul, the middle-silurians (Simla slates) are missing as well as the conglomerates. I think the explanation is the same in both cases; namely, that the upper-silurians, in the section through Dainkund, and the upper and middle silurians, in the Siul-Rávi section, have been squeezed out in the flexions in which the strata have been involved. It is to be noted that in the Siul-Rávi section, where both the upper and middle silurians are missing, the Dainkund gneissose granite has reached its minimum development, being reduced to a narrow band of gneissose aspect, a fact which does not favour the hypothesis of the "absorption" of the missing beds by the rising granite, or of their having been metamorphised out of recognition by contact action.

I note in passing that though I have, for the sake of simplicity, in the diagrammatical sections I and II, represented the upper-silurians as unbroken beds of conglomerate, I by no means overlook the possibility that they may contain slates of a slightly higher or lower horiz The plications in which all these rocks have been involved have been very great, whilst fossil evidence is *nil*. The conglomeritic series is not uniformly conglomeritic, and therefore the probability of other beds, slightly higher or lower than the conglomerates, having been folded up with them, is very great. Further observations on this subject will be found in part I of this paper.

I desire to point out, in conclusion, that the inference must not be drawn from any remark made in the preceding pages, that I deny the existence of true metamorphic gneiss in the North-Western Himalayas. In a recent paper I have

[1] The Siul runs under Bhale (Balai) and Manjere.

distinctly indicated my belief that some of the crystalline rocks in the North-Western Himalayas are metamorphic gneisses,[1] and the fact will be definitely asserted in a paper on the section from Simla to Wangtu that will appear in a future number of the Records; but I think it would be a grave error of judgment were we to allow the presence of metamorphic rocks of this character in the Himalayan area, to blind our eyes to what appear to me to be the leading facts in the past history of he Himalayas; namely, that volcanic eruptions on a large scale in upper-silurian and lower carboniferous times were followed by a gradual subsidence of the Himalayan area which lasted through several geological ages. A period of elevation which has not yet terminated, then set in, during which the strata, that had accumulated during the period of subsidence, were crumpled and compressed to an enormous extent; the period of elevation being marked by a re-kindling of the volcanic fires, the gneissose granite of the North-Western Himalayas misnamed "central gneiss" constituting the deep-seated portions of comparatively modern eruptive rocks. In short, the past geological history of the Himalayas is inseparably connected with volcanic activity.

Memorandum on the probability of obtaining water by means of Artesian Wells in the plains of Upper India, *by* R. D. OLDHAM, A.R.S.M., *Geological Survey of India.*[2]

In the broad plains of Upper India the need of an abundant supply of pure water must always be felt, and it is consequently not surprising that in the search for it borings have been sunk to greater depths and prosecuted with greater ardour than any that have been sunk in the search for coal. Of the many papers and reports bearing on this question, I do not propose to discuss more than the one published by Mr. Medlicott,[3] where the possibility of making a successful artesian well is discussed on the not unnatural assumption that there is a continuous zone of gravel and sand deposits, comparable to those of the *bhábar*, separating the clay deposits of the alluvium from the rock below.

2. In the case of alluvial deposits, such as those of the rivers of the Indian peninsula, which have been formed as the land gradually sunk, a zone of coarse deposit will be found lying immediately upon the rock; but with the Gangetic alluvium the conditions are different, inasmuch as we have ample reasons for believing that the Himalayas were raised *pari passu* with the depression of the plains; and in this memorandum I propose to enquire how this would affect the assumption made by Mr. Medlicott in his memorandum already referred to.

3. Many different theories of mountain formation have been propounded at various times and by various authors, the latest of which is that of the Rev. O. Fisher, which demands that flanking every mountain range subject to denudation there should be a corresponding depression in which deposition is taking place, that the depression should extend by encroaching on the land separated by it

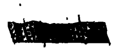
[1] Records, XVII, pp. 60 and 70.
[2] With this paper should be read the one following.
[3] Records, XIV, p. 205.

Section I through Damkund and Tisa to the Sach Pass

Section II through Damkund Odapura, Huth, and Chánju

Section V

Section IV



Section III

A Tertiary series B. Carbo triassic series. C. Upper silurian conglomerates.

D Middle and lower silurians. E. Pre Carboniferous trap G. Gneissose granite

Longitudinal Scale of I and II. 1. Inch = 10 Miles.

from the mountain range, and that at the same time the deposits formed on the skirts of the mountain range should be gradually elevated and exposed to denudation. To take the case of the Himalayas, the mountain range would at first be small, and the corresponding depression also small; but, as the elevation of the Himalayas proceeded and the Gangetic depression increased in depth and width, the deposits formed along the foot of the hills would be disturbed, elevated, exposed to denudation, and form an integral portion of the Himalayan range; this encroachment of the hills on the plains would, however, be more than balanced by the encroachment of those on the land to the south, so that as the Himalayas increased in height, the Gangetic plains increased in width and the alluvium of which they are composed in thickness. Mr. Fisher has not followed up his theory beyond the growing stage of a mountain range; but, however interesting it might be to be able to prophecy the decay and extinction of the Himalayas and the plains of Hindustan alike, it would have no practical bearing on the question I am now considering, and I shall confine myself to enquiring whether the known facts fit in with Mr. Fisher's theory as far as he has carried it and, secondly, how, if true, it will affect Mr. Medlicott's fundamental assumption.

4. In the first place, are there any indications that the alluvial deposits extended further north than they now do? Most certainly there are; for there can be no reasonable doubt that the Siwalik beds were the *bhábar* deposits of their day, and that the ground they now occupy must have formed the northern margin of the Gangetic plain. But this does not sum up the whole of the matter; in every section of the Siwalik that has been examined we find at the base beds in which clays preponderate, and above these comes a great thickness of sandstone which passes upwards into conglomerate.

5. At the present day there are everywhere along the foot of the hills great banks of shingle formed by the streams whose velocity is checked as they issue from the hills, below the shingle come great stretches of sand, and beyond these again is the clay of the alluvial deposits proper. But as the shingle banks are added to, they must encroach on the sand, and this again on the clay deposits, and in course of time a section precisely similar to that to be seen in the Siwaliks will be produced, from which we may conclude that then as now the coarser deposits were being pushed forward from the north over the finer.

6. Nor does the strip of hilly country occupied by the Siwalik beds represent the whole of the southward encroachment of the Himalayas, for, close up against the older rocks of the Himalayas, we find sandstones and clays, which could not have been formed in that position, but must originally have been separated from the hills by a strip of country on which the streams deposited their coarser debris. From these facts we see that even the boundary of the Himalayan slates does not mark the original southern limit of the Himalayas, but that it must be placed somewhere, though not necessarily very far, to the north. To judge by analogy, it must have been on the average at least twelve miles further north in Náhan, and six in Middle Siwalik times, than the present main boundary of the slates and the Siwalik.

7. In the light of these facts, the assumptions that there is a continuous zone of coarse deposits, continuous with the existing *bhábar*, next to the rock floor of

the Gangetic depression, and that the deposits will become coarser on the whole as we sink into the alluvium at any point are not justified. At first, doubtless, coarser deposits were overlaid by finer ones, and in the southern margin, where the land has sunk and the alluvium spread over it, this still takes place, but at the northern margin,—and it is with this alone that we are concerned,—the coarse deposits have for long past been pushed forward over the top of the finer, and all direct connection with the coarse-grained bottom bed cut off by the elevation of the strata we now call Siwalik.

8. The only means we have of testing these suppositions are the Ambala and Calcutta borings. According to the hypothesis I have put forward, the beds should become finer on the whole, as a greater depth was reached in the first case but coarser in the second. With regard to the Calcutta boring,[1] an inspection of the record will show how markedly this is the case; in the Ambala boring the finding pebbles low down might be held to disprove the hypothesis; but, as far as I can make out, they were merely occasional small pebbles never forming shingle properly so called; and the table (given below [2]) of the thickness of sand and clay passed through in each hundred feet shows clearly that the deposits did on the whole increase in fineness with the depth reached; for, while in the first 400 feet sand was in excess of clay, during the next 300 the thickness of clay was greater than that of sand, and the proportion of clay throughout the section increased steadily till in the last 100 feet there was but 7 feet of sand in all.

9. Since, then, the sections met with in these borings are so strikingly in accord with what, according to hypothesis, they should be as almost to amount to proof, it is extremely probable that, as indicated in § 7, there is no zone of coarse permeable deposits continuous with those of the *bhábar*, and that in consequence there is but little prospect of obtaining water, except in small quantities, by means of artesian wells in the plains of Upper India.

Further considerations upon Artesian sources *in the* plains of Upper India, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

In the foregoing paper Mr. Oldham makes use of the artesian question as a peg whereon to exhibit a very neat combination of theory and observation to elucidate the formation and resulting structure of the Sub-Himalayan deposits, including those of the great alluvial plains, in their relation to the growth of the mountains themselves. I am glad to have afforded the opportunity for so interesting and instructive a discussion, and glad also for the occasion it gives me in return of adding some further considerations upon the same subject; it is

[1] Rec., Vol. XIV, p. 221.

[2]

0 ft. to 100 ft.	Sand 59 ft.	Clay 37 ft.	Soil	4 ft
100 „ to 200 „	„ 56 „	„ 42 „	Kunkur	2 „
200 „ to 300 „	„ 58 „	„ 42 „		
300 „ to 400 „	„ 54 „	„ 46 „		
400 „ to 500 „	„ 46 „	„ 54 „		
500 „ to 600 „	„ 37 „	„ 63 „		
600 „ to 701 „	„ 6 „	„ 95 „		

however very needful to point out that criticism, both in its positive and its personal aspects, is quite too serious a responsibility to be treated as a lay-figure. It is easy to show that the dummy set up, to be so expertly knocked down again, never occupied the position assigned to it in the place whence it was taken. The condition in question—a continuous zone of gravel and sand deposits comparable to those of the *bhábar* separating the clay deposits of the alluvium from the rock below—may in Mr. Oldham's opinion be necessary to the success of arte-sian borings, and he is of course entitled to maintain it, but he was not warranted in representing it as "the fundamental assumption" of the paper he referred to. That condition is indeed there quoted as theoretically most favourable, especially as affording assignable limits of depth, but by illustration and example it is abundantly shown that success does not depend upon the supposition of which that condition would be the result.

2. The study of Mr. Fisher's admirable work[1] had the same effect upon me as upon Mr. Oldham, up to a certain point, to upset a supposition of primary sim-plicity regarding the underground conditions of the great plains; but as I had never held or represented that supposition to be essential to the existence of arte-sian sources, there was no occasion to proclaim a correction that might discourage a project which I hold to be quite independent of that particular arrangement. I did not however fail to represent the whole case on the first opportunity, and to indicate its bearings on the question of artesian sources, in a geological paper written two years ago for the Gazetteer of the Punjab, but which has not yet ap-peared. The following paragraphs (3 to 11) are reprinted *verbatim* from proofs that were set up in 1883.

3. "We have still to notice the depth or thickness of these deposits, as a point of practical as well as of speculative interest. The surface deposits belong every-where, as we have seen, to the human period. In a cutting near the head of the eastern Jumna canal, Colonel Cautley dug out a fossil town.[2] Everything below is concealed. It would seem that near the 'outer' margin, *i.e.*, on the Himalayan side, of the plains a very close limit to the age of any beds conformably under-lying the recent alluvium should be assignable; for the topmost beds of the Siwalik series, of latest pliocene age, if not pleistocene, are tilted up vertically; yet they are indistinguishable in composition and texture from the actual river de-posits. Disturbance of such magnitude must, one would think, have extended to some distance south of these outcrops, and thus have involved total unconformity of the Siwaliks with any beds that are still undisturbed, within a considerable distance. If this were so, it would follow that any beds conformably underlying the surface deposits in the neighbourhood of the Himalayan margin must be long post-Siwalik. But, as will presently be shown, the disturbance to which the up-heaval of the Siwaliks is due probably extended to only a small distance from that margin.

4. "Far from the mountains, anywhere within the protecting influence of the underlying hard rocks of the peninsula, it is evident from what has been said that the plains deposits might be in unbroken sequence with the whole tertiary

[1] Physics of the earth's crust, by the Rev. Osmond Fisher, London, 1881.

[2] Journal, Asiatic Society, Bengal, III, p. 43, 1834.

system; and on this 'inner' border of the plains even at the small depth to which observation has access, beds having some small comparative antiquity occur in close relation with the surface deposits. In the lower reaches of the Jumna, between Agra and Allahabad, where the river has eroded its channel to a depth of 100 feet below the level of the adjoining plains, bones of extinct forms having some affinities with those procured from the upper Siwalik strata have been found in perfectly undisturbed clays.

5. "Any surmise upon the underground features of the plains deposits can only be derived from the view formed of antecedent conditions as indicated by the features of adjoining areas. On the peninsular side there is good evidence to show that, so far back as in immediately pretertiary time, the drainage flowed from the south towards what is now the Gangetic basin: the whole northern scarp of the Vindhyan plateau existed at that time in approximately its present position. The Deccan trap poured over that scarp on to the gneissic area of lower Bundelkhand. How far it may have flowed over the low ground in that direction it would be impossible to say; on the plateau it does not seem to have reached so far north as Gwalior. The total absence of any remnant of tertiary rocks on this border of the peninsula suggests that it was then out of the reach of deposition, rather than that all such deposits have been since removed; but it would seem pretty certain that this drainage basin was part of that in which the eocene rocks of the Himalayan border were laid down. Only the lower stage of that series is marine; and the muddy character of these beds, contrasting with the clear limestones of the same age in the western Punjab, suggests estuarine conditions requiring a southern bank far to the north of the present south boundary of the plains, and of course also a limiting land in the actual Himalayan area. Already in nummulitic time these marine bottom-beds became mixed with and soon permanently replaced by others of distinctively Sub-Himalayan characters, consisting of fluviatile deposits with terrestrial and fresh water fossils; and these conditions have lasted throughout the Siwalik epoch to the present day, for, as has been said, the top Siwalik strata seen at many places in the Panjab are absolutely indistinguishable from those of the plains. These middle and upper tertiary fluviatile deposits were independent of the sea level, and would have spread over the whole basin according to its contour, and equally to the south in the valleys of the northern slopes of the peninsular area now concealed beneath the plains. From the foregoing observations it would appear that the Sub-Himalayan eocene marine basin was probably a narrow one; but that the supervening upper tertiary fluviatile deposits may have stretched southwards to an indefinite distance.

6. "To the foregoing consideration of the original conditions of the basin, there must be added what can be said regarding the Himalayan disturbance as affecting the floor, and therefore the whole condition, of the plains deposits. The extreme unconformity already mentioned as occurring between the horizontal plains deposits and the vertical Siwaliks along the Himalayan border, does undoubtedly establish an immense lapse of time (as reckoned in historical periods) between the two. But the inference as to how far this condition of unconformity extends beneath the plains to the south of the actual boundary depends upon the view

taken of the process of disturbance. It is difficult to resist the *primâ facie* impression, from the sight of an immense thickness of stratified rock turned up on end that great violence must have attended such results, and hence that the effects must have extended to far beyond the point where such intensity is exhibited. It was upon such natural impressions that the cataclysmal theories of the early geologists were founded. In the present case, the plausible supposition from such a point of view would be, that an elevation of the Himalayan area, coincident with the contortion of the Siwalik strata, had first resulted in a great valley of erosion from the mountains to the sea, forming a clean-swept basin for the deposits which now form the plains.

7. "To give meaning to this seemingly useless discussion it may be well to point out that it forms the only rational approach to the practical question often asked—where in the plains and at what depth would there be a prospect of success for an artesian boring? If the supposition just noticed might be counted upon, a very favourable answer could be given to this question. The base of the deposits would then be everywhere within reach; that base would generally consist of coarser materials, such as would form a capacious water-stratum; and it would be in continuous connection with the present upper zone of gravel beds at the foot of the hills, where copious absorption of water occurs.

8. "Careful observation and reflection are, however, against that *primâ facie* supposition. It will be shown that before the disturbance of the Siwalik rocks (*i.e.*, during the Siwalik period) the Himalayan rivers, great and small, flowed just where they now do in the mountains; so that there is nothing to support the supposition that any great elevation or violent movement of any kind accompanied the disturbance of the Siwalik rocks; for they probably were tilted up so slowly that the main rivers could *pari passu* erode their gorges across the rising strata. Another fact of corresponding import is found in the form taken by the Siwalik strata under disturbance. The *dúns*, or longitudinal valleys occurring so constantly inside the Siwalik ranges, are generally formed of the topmost Siwalik strata in a more or less horizontal condition, rising by a gradual increase of dip to form the range outside the *dún*, while on the inner side they either abut abruptly against the rocks of the inner range, or else are bent up sharply to form that range. Such a feature strongly suggests the probability that the final limit of the disturbance may be no less abruptly marked; so that beyond the extreme verge of the vertical Siwalik strata, these same strata may have remained permanently in their original gentle slope of deposition, and would thus be in conformable sequence with the most recent deposits of the plains within a very short distance of the hills. It is independently intelligible that the slow compressing force to which the bending of the strata and the consequent rise of the hills were due, would expend itself to the utmost on each flexure before giving rise to a new one.

9. "Such a process would of course involve great erosion of the Siwalik strata in the immediate region of upheaval; and there is abundant evidence of this, not only in the river gorges and the deep ravines of the minor streams, but along the whole outer edge of the hills, where, as a rule, the uppermost gravel beds of the plains rest upon the edges of low Siwalik strata near the axis of the

flexure, the whole of the outer and steeper side of which has been removed. Under the supposed conditions of disturbance this denudation would not have reached far; so that within a short distance there might be completely conformable sequence between the Siwalik deposits and those of the actual plains.

10. "One important direct observation has been made upon the underground constitution of the plains, in the boring for an artesian spring at Ambala to a depth of 700 feet. No gravel bed or other water stratum was met with, and the boring ended in stiff clay. If this section could be taken as representative, it would be conclusive evidence against the supposition of these deposits lying in a simple post-Siwalik basin of erosion; for the bottom of such a basin must at Ambala be within a much less depth than 700 feet, and the basal beds in such a basin must as a rule be coarse, porous, and water bearing. It is easy to explain a possible exception to this rule; and Ambala is just in the position where such an exception would be most likely to occur. It is about 20 miles from the foot of the hills, and this is beyond the distance to which gravel is now swept by the small streams and the rain-wash on the steeper slopes near the hills. It is only within the range of the great rivers, in the deeper parts of the supposed basin of erosion, that coarse deposits must occur somewhere in almost every section, especially at or near the base; and in river-formed deposits such as these, the range of the great rivers embraces in time more or less the whole area. Ambala, about midway between the Jumna and the Sutlej, and so near the hills, is just in the position most likely to escape that influence, as the whole growth of deposits might be directly from the hills, or by overflow of finer sediment from the main rivers. In this way there might be nothing there to mark the bottom of the basin or surface of erosion in so small a section as that given by a boring; and thus the passage from the recent plains deposits into beds of such similar composition as are those of the upper Siwaliks would not be noticed. It can however be affirmed that the boring did not reach beds that had undergone any considerable disturbance, for the frequency of alternation of beds in the lower part of the boring was as great as in the upper part, whereas a very moderate tilting of the lower beds would have given a perceptible apparent thickening of the several strata passed through by a vertical boring.

11. "There is yet to be taken into account a consideration of great weight in this discussion. It was long ago suggested by Herschell,[1] in seeking for a prime mover of the forces by which crust movements are effected, that the familiar process of denudation by the continual removal of matter from steep elevated tracts and the deposition of it in adjoining low ground, evidently disturbs the equilibrium of strain beneath those areas, causing a tendency to elevation in the former and to depression in the latter. Recent researches upon the nature of the earth's rigidity entirely confirm that inference; and it is the obvious explanation of the constantly observed fact of depression in deltas. Borings in the delta of the Ganges at Calcutta have discovered land surfaces far below the present sea level. Now these conditions occur in a very concentrated form along the fringe of the Himalayan border. An enormous amount of detritus is annually swept down from the mountains, a relatively large proportion of it being from the

[1] In note I to Babbage's Ninth Bridgewater Treatise, 2nd edition.

softer rocks of the Sub-Himalayan hills; and a relatively large proportion of that detritus is deposited in the upper marginal region of the plains. It thus becomes a matter of certainty that depression to an unknown extent has taken place in this latter area. This view considerably modifies the inference to be drawn regarding the lower beds in the Ambala boring as based on the supposition of extensive elevation and erosion. The probability would now seem to be that the boring did not reach beds of Siwalik age. It is evident that these later conclusions regarding the underground relations of the plains' deposits render more difficult than ever any speculation as to the position or depth of an artesian source, although by no means shaking the probability that such sources occur there."

12. These last words show how little dependence was placed upon the hypothetical condition of a continuous post-Siwalik surface of erosion covered by coarse deposits beneath the alluvium of the plains. Thus, from quite opposite sides, though from the same suggestion of a slow rising of the mountain area and depression of the adjoining region, Mr. Oldham and I have independenly shown the non-existence of the condition which he has characterised as the fundamental assumption for the success of artesian wells. Although in the paper under reference I gave ample proof that no such condition was necessary, I must plead guilty to having myself exaggerated not only the chance of its occurrence, but also its importance. From figure 1 of the experimental results (*l. c.*, plate facing page 207), it is apparent that any approach to a complete fulfilment of that condition would be fatal to success as affording equal capacity for percolation throughout, and therefore no compulsion to a rise, beyond what might be due to variation of slope. The proclivity to exaggerate the importance of this condition is the desire to make sure of porous deposits throughout, and their continuity from the source of supply; but it is plain that sufficient assurance on this point may be established without the assumption in question.

13. In the first place there is much misapprehension as to the facts of porosity and percolation. Although the statical porosity, the capacity for holding water in the interspaces, is the same in granular bodies whether the grains be large or small, the dynamical porosity, the facility of percolation, is much greater in the latter case, because of the much less surface of contact involving friction. Thus in the experiments described in the paper under reference, the discharge from the pipe (fig. 1) was 12 cubic inches per minute when filled with large shot (B. B.), and only 5 when filled with small shot (No. 8), the discharge from the same pipe when free being 322 cubic inches. A great mistake is however made in applying this fact to rocks. Conglomerates and gravels are not, except very rarely, made up only of large and small stones; there is always a matrix, generally of sand; so that in point of fact, gravel is less porous than sand, for every pebble is so much potential porosity abstracted. Sand of some sort is therefore, in every case, the effective medium of percolation. The maximum or normal porosity of a body composed of equal spherical grains, is about 40 per cent.[1]

[1] The Ganges sand at Narora is stated by Colonel Brownlow, R.E., to absorb 2·5 gallons of water to the cubic foot, *i.e.*, 40 per cent.

14. Next as to distribution: from Mr. Oldham's rough statement of the case it would be understood (though of course he did not mean it) that only clay deposists take place at a distance from the upper margin of the plains, but as a fact it is certain that the great rivers bring down sand in abundance to the very delta. In the total burden of solid matter discharged from the mountains, sand is certainly the chief ingredient, and I do not see how it can be doubted that such deposits were more or less freely continuous throughout the areas over which these rivers spread. The occurrence that took place last year in sinking a well in the Ganges for one of the piers of the railway bridge at Benares, when the well was burst by a sudden influx of water from below a bed of clay rising to a greater height than the river water outside the well, proves that partial artesian conditions exist at shallow depths, near to the lower margin of the plains. It is in the areas of tranquil inundation between the great rivers that deposit of clay prevails. The alternation of the two kinds of deposit is secured by the necessary process of growth whereby depositing rivers must in time change their course impartially over their basin of deposition. In taking the Ambála boring as a type of what may be expected in the plains, Mr. Oldham has ignored how peculiarly its position excludes it from being taken in that sense as is explained above (§ 10). In sinking the piers of the Jumna bridge east of Ambála at the same distance from the hills, large boulders were found at 40 feet below the bed of the river. It is no doubt conceivable that even in the open plains some spots may have successively escaped any adequate amount of sand deposit during the repeated oscillation of the great rivers; but on this point also much misapprehension exists as to what occurs in nature. In an official discussion upon this question, it was urged that the possible porous layers in these deposits would be represented by long strips corresponding with the courses of the great rivers, the idea being taken from the rivers of Upper India as now exhibited. But this is misleading; for these rivers now for the most part run in valleys of erosion, and are not adding to the adjoining plains. The state is very different under formative conditions, when the river in flood runs at the general level of the country and distributes its branches over a wide area, as is now the case with the Brahmaputra in Upper Assam. I therefore maintain that there is a strong presumption that porous beds do occur at various depths over a large proportion of the plains, and that they are almost necessarily in connection with like deposits up to the base of the hills.

15. Any one who has realized the process of growth of the plains deposits as indicated above, can have no difficulty in meeting the objection suggested by Mr. Oldham as to the state of things at the origin of the deposits, which is the third condition of success. Even granting his main contention that as the mountain border rises or the plains are depressed there is a growing tendency to widen the zone of coarser deposits by extension over fine deposits that had previously been laid down, the whole argument is only valid against the aforesaid fictitious "fundamental assumption." Though the ultimate general tendency may be as stated, it is quite certain that from the beginning the process was exceedingly irregular; that while the streams were pushing their coarser deposits in one direction, the finer deposits in the other direction must have encroached upon the

coarser deposits of a previous period,[1] and so the resulting structure of the deposits in this region must be an entanglement of projecting wedges of coarser deposits between sheets of non-porous beds, thus producing the conditions most favourable for artesian sources as illustrated in the experiments given in my paper (*l.c.* p. 207)—a large sectional area of water-holding deposits at the head of supply, tailing off into beds of less capacity and between impervious beds. If there were any need to do so for the present argument, I think that a strong case might be made for an extension of the early post-Siwalik *bhábar* much beyond the range of the actual *bhábar*. The upper edge was certainly considerably nearer the plains originally than at present; for now it for the most part occurs along the axis of flexure, in contact with middle Siwalik strata, having overlapped the denuded edges of the Siwalik conglomerates; and it seems to me highly probable that in the early stages of Siwalik elevation, when the now buried conglomerates were under active denudation, the resulting *bhábar* may have reached much beyond the present limits of this zone, beneath the finer deposits of the present plains. I do not think that the fact of such depression as contemplated by Herschell or Mr. Fisher would practically have any direct effect upon the conditions of water percolation as originally established in the process of deposition.

16. When I first noticed in 1864 (Memoirs III, pp. 182-5) that there seemed a fair chance for successful artesian borings in the Gangetic plains, although Sir John Herschell's pregnant suggestion was in view (*l.c. p.* 198), I did not then consider the point which we have now shown to have little practical bearing on the question. My recommendation was based on the general aspect of the conditions. In 1867, a definite project for a boring at Ambála was referred to me for opinion. I then referred to a number of successful artesian borings in analogous positions, and quoted them as confirming my originial recommendation.[2] These examples were particularly instructive in showing how little did success depend upon any regularity in the deposits; how, among the promiscuous interlapping of fluviatile deposits, the continuity of water-bearing strata is somehow and in variable degrees sustained. Thus, when it came to the point, my recommendation rested chiefly on instances of success under like conditions, rather than upon theoretical grounds. On the occasion of successful artesian borings at Pondicherry, I again took up the question and discussed it in a more systematic manner in the paper under reference (*supra*, XIV, pt. 3), giving numerous examples. That at Venice may again be referred to with advantage in the present connection. It is in a deltaic area, below a broad *bhábar* zone which rests against disturbed pliocene strata at the foot of the Alps, the features thus in every respect corresponding to those in the case under consideration. The area, too, is one of considerable depression; the boring begins at about sea-level, and several old land

[1] Close to Hardwár, within the mouth of the gorge of the Ganges through the Siwaliks, a bed of stiff clay is seen resting upon coarse boulder gravel. Memoirs, Vol. III, pt. 2, p. 153. In the Siwaliks themselves the outermost (highest) beds seen are alternating clays and coarse conglomerates dipping at 80° towards the plains. *Ibid*, p. 118.

[2] The papers are published in No. 178 of Selections from the Records of the Government of India, Home Department, p. 47.

surfaces were passed through to a depth of 400 feet. No coarse deposits of any kind were struck within the depth explored (422 feet), only clay and sand with the occasional layers of peat that had once formed the land surface. The copious water bed occurred in sand at a depth of 200 feet. The circumstances of the Gangetic plains differ only in respect of magnitude. This is no doubt in itself presumably adverse, owing to the greater friction to be overcome in the percolation of the water stratum. On the other hand, these relative magnitudes are often self-compensating, and it would, I think, be a mistake to decline experiment in a matter of such importance for theoretical reasons of uncertain applicability.

17. After careful reconsideration of the whole case in the light of the rather imaginary difficulty raised by Mr. Oldham, I have to reaffirm my conviction that there is reasonable prospect of success.

18. It is most unfortunate for the cause that the experiments that have so far been made were fixed upon solely on grounds of local need, and not as in any degree favourable sites for testing the conditions. It has been shown above that Ambála is in a position most likely to be out of reach of water-bearing deposits, comparatively near the hills and midway, at a considerable distance, between the great rivers which are the vehicles for such deposits; and now a trial on a large scale is being made at Agra, for which I am in some degree responsible. I could not say there was no chance of success, but I did not fail to say it was about the last place I should choose for a trial boring. In discussing the question with the engineer who was getting up the projects for the water-supply at Agra, my written opinion was as follows:—"Agra is not perhaps the most propitious position for a boring, and if I were starting a series of experimental borings, I would not begin there, because of its much greater proximity to the south margin of the basin, while the water-supply to be expected would, I think, be from the north. Although Agra is now at the lowest point of the basin, the hollow of the original depression was much more to the north, the change being due to the more abundant supply of detritus (by rain and rivers) from the north, and the consequent encroachment and overlap of deposition from that side. Thus the boring at Agra will be in deposits having a different source of origin from those through which the water-supply is expected; and although the strata are contemporaneous and in the same basin, the continuity of porous or non-porous strata, and hence the connected percolation, may not be as free as if the boring were altogether in beds of northern derivation." Subsequently, in answer to a formal reference from the Government of the North-Western Provinces on the subject, I wrote (1st December 1881)—"It only remains for me to say that the grounds of possibility and hope are sufficient to recommend another trial. In order of merit I would choose Bareilly, Shajehanpore, Fyzabad, and Lucknow as propitious positions. Regarding Agra, I have already given an opinion, quoted in Major Jacob's report on the water scheme for that place. Although holding that an artesian spring would not be hopeless there, I was careful to point out that it was by no means a propitious place for a new venture, on account of its great distance from the northern sources and its actual proximity to the southern edge of the basin." It is obvious that the friction difficulty will be at its maximum here, and the free connection with the head of underground water at its minimum. On the

19th of February the boring had attained a depth of 481 feet, with the section given in the following table. The thin bands of sand Nos. 30 and 32 are probably isolated in the clay. The experiment certainly cannot be considered as fairly completed at this depth.

Section of Artesian boring at Agra, 1884-85.

No. of bed.	Thickness of bed.	Depth.	
1	16	16	Loam.
2	10	26	Sand, loamy, with small kankar.
3	10	36	„ loamy.
4	8	44	„ fine.
5	19	63	Clay, loamy.
6	27	90	Sand, loamy (sweet water).
7	20	110	Kankar and sand.
8	29	139	Sand, white, and sandstone (water brackish).
9	5	144	„ white with kankar.
10	22	166	Clay, loamy.
11	58	224	„
12	56	280	„ loamy.
13	16	294	„ and kankar.
14	2′ 6″	296′ 6″	Kankar.
15	1′ 6″	298	Clay, loamy.
16	3′ 6″	301′ 6″	„
17	1	302′ 6″	Kankar.
18	8′ 6″	311	Clay.
19	1	312	Kankar.
20	15	327	Clay.
21	11	338	Sand, loamy.
22	7	345	„ red, and kankar (a little water).
23	15	360	Loam.
24	1′ 6″	361′ 6″	Kankar.
25	18′ 6″	380	Clay and kankar.
26	10	390	„ loamy.
27	4	394	„
28	2	396	Kankar.
29	44	440	Clay.
30	3′ 9″	442′ 9″	Sand running, full of water.
31	23′ 9″	467′ 6″	Clay, loamy.
32	3	470′ 6″	Sand running, full of water; some large angular grains of quartz and felspar.
33	10′ 6″	481	Clay.
34	......	......	Sand (dry), with small ferruginous concretions.

Notes on the Geology *of the* Aka Hills, Assam, *by* TOM D. LATOUCHE, B.A., *Geological Survey of India.* (With a map.)

In December of last year (1883) I obtained permission to accompany the expedition against the Akas, a tribe occupying the Lower Himalayas to the north of Tezpur in Assam, between the Bhutias and Daphlas. Although these hills had not been surveyed before, yet the observations made by Colonel Godwin-Austen in the Daphla hills about 40 miles to the east, and published by him in the Journal of the Asiatic Society of Bengal, Vol. XLIV, Pt. II, had shown a

sequence of rocks similar to that found by Mr. Mallet in the Sikkim area to the west (Mem. Geol. Surv., India., Vol. XI, Pt. I), and therefore it was probable that, as the Aka hills are physically continuous with those on either side, the same rocks would be found in them, and this I found to be the case. Representatives of the rocks described by Mr. Mallet as occurring in the Teesta valley, *viz.*, Tertiary, Damūda, and Daling, were found *in situ*, and judging from the number of boulders of gneiss brought down by the rivers crossed during the expedition, there is no doubt that this rock forms a great part of the country to the north of the Daling series.

The first hills met with to the north of Tezpur form a long ridge on the south bank of the Borholi river, rising to 800 or 900 feet above the plains of Balipara. This ridge is of pleistocene age and consists entirely of an unstratified drift of well rolled boulders and pebbles derived from the hills to the north, gneiss and granite being the predominating rocks. Quartzites and hard sandstones from the Damudas and Tertiaries are also common. To the north of the Borholi, following the route taken by the expedition up the Diju stream, similar beds of drift form low hills and terraces on either side of the stream for 7 or 8 miles. This great accumulation of drift is probably the result of torrential action due to the greater extension of the Himalayan glaciers in post-tertiary times.

About 8 miles from the Borholi, the Diju valley becomes narrower, and beds of tertiary rocks are seen *in situ* on the banks of the stream. These are light-grey sandstones, with beds of shale sometimes carbonaceous, much crushed and locally contorted, dipping to north-east at 55°. Further into the gorge other exposures are seen of micaceous fissile sandstone with shales dipping always at high angles to the north-east and becoming vertical at camp No. 1, about 12 miles from Dijumukh. In a large boulder of the sandstone in the bed of the stream, I noticed a fossil tree trunk about 1 foot in diameter, coated by a layer of lignite one inch thick, but one found no lignite *in situ*, nor did I see any fossils.

At camp No. 1, the path left the Diju and led over a ridge about 1,200 feet above the stream to camp No. 2 on the Maj Borholi. Owing to the dense jungle I could find no sections of the rocks forming the ridge, but the fragments on the path were all of brown ferruginous sandstone.

In the Maj Borholi valley the rocks exposed were entirely different from the soft tertiary sandstones of the Diju, and consisted of hard grey quartzitic sandstones interstratified with carbonaceous shales and seams of coal, the whole much crushed and contorted. A good section was obtained in a small stream running north into the Maj Borholi at camp No. 2. Here the rocks were dipping at high angles to the south, and the following beds were exposed, in descending order:—

		Ft.	Ins.
Light coloured quartzitic sandstones, much jointed	about	20	0
Shales with bands of sandstone 1 to 2 feet thick		45	0
Coal, fairly constant in thickness		1	6
Black shales		8	0
Dark grey sandstone		2	0
Hard dark coloured sandy shales		8	0

		Ft.	Ins.
Coal, thickness variable, much crushed	over	1	0
Light grey coarse quartzite with strings of flaky coal		60	0
Dark coloured sandy shales		5	0
Coarse hard grey quartzitic sandstone	about	8	0
Light coloured shaly sandstone		6	0
Black shales, centre portion very carbonaceous		4	0
Soft grey micaceous sandstone		14	0
Hard dark coloured micaceous sandstone and sandy shales with a thin seam of flaky coal at the base		25	0
Hard grey quartzitic standstone		?	

Above this section slips have occurred in the sides of the gorge, and where the rocks appear again they are so much contorted and crushed that it is impossible to identify the different beds, or to form any correct estimate of the thickness of the whole series. The Borholi above the camp runs along the strike of these beds, and outcrops of carbonaceous shale and coal occur at intervals for about 2 miles up the river; outcrops also occur on the north bank. On the return route from Jamiri to Balukpung, about 8 miles to the west, I was unable to identify this band of coal-bearing rocks with certainty owing to the dense jungle, but near the camp between Jamiri and the Borholi, we crossed some carbonaceous shales on the same line of strike which are probably a part of this series. These coal-bearing rocks are identical in position and composition with the Damudas described by Mr. Mallet in the Sikkim area, and found by Colonel Godwin-Austen to the east in the Daphla hills.

From camp No. 2 the path led over a jungle-covered ridge to the north, rising to 4,000 feet above the Maj Borholi, and descended about 3,000 feet to the Tenga Páni. Blocks of a micaceous slaty schist were common on the path, and in the Tenga Páni this rock was seen *in situ*, striking east and west, and nearly vertical. Some of the beds were very fine-grained and fissile, and might do for roofing slate, but their distance from the plains and the ruggedness of the country between render them practically useless. To the north of the Tenga Páni similar slaty schists form the ridge on which the Aka villages Mahdis and Labris are situated, rising to 6,000 feet above sea level, and extend to the west to and beyond the village of Jamiri, where they are silvery greenish mica schists, sometimes slightly talcose. These rocks are probably the equivalents of the Daling slates and schists of Sikkim, but I nowhere found any dolomitic beds or representatives of the Baxa beds as described by Mr. Mallet. And as I found no sections showing the junction of the Damudas and Dalings, I cannot throw any light upon the question as to which of these series is the older.

As to the practical importance of the coal seams in the Damudas, very little need be said. Even if the seams were thick enough to be worked, and not broken up and crushed as they are, their distance from the plains and the difficulties of transport would prevent their being worked with profit, especially as there are much larger coal-fields in Assam, and more easy of access, which have never been touched as yet. Even in the Teesta valley, where these Damuda beds contain thicker seams of coal close to a line of railway, the attempts to work them have so far resulted in failure, principally owing to the crushed condition in which the coal occurs, and the consequent necessity for a costly process to consolidate it.

Of other mineral products the country appears to contain little or none. The tertiary rocks contain a little lime which is here and there deposited as tufa by streams on the face of cliffs, and doubtless there are layers of lignite, but neither of these exist in sufficient quantity to be of any use.

On the alleged tendency of the Arakán Mud Volcanoes *to burst into eruption most frequently during the rains ; by* F. R. MALLET, *Deputy Superintendent, Geological Survey of India.*

On the 10th December 1884 an eruption occurred from one of the Cheduba Mud Volcanoes, concerning which we have not as yet received any information officially. It was, however, witnessed by Captain H. G. Creft, Commander of the British India Steam Navigation Company's vessel *Coconada*, while passing through Cheduba Straits, and, in a letter received from him on the subject, Captain Creft describes the eruption as having been "of very short duration, not more than eight minutes, but while it lasted the flames must have been quite 400 feet, accompanied with large volumes of smoke."

As mentioned in a previous volume,[1] a notion is prevalent amongst the Arakán Islanders that eruptions from the mud volcanoes occur more frequently during the rains than at other times of the year. Were such an idea confined to the islands in question, it might possibly not be worth much investigation, but a very similar one is entertained with reference to the mud volcanoes of Java, which are said to explode most violently in the wet season. The main object held in view in recording the Arakán eruptions is the collection of sufficient materials for putting the truth of such supposed periodicity to the test. To generalise with safety, a far more extended record must be available than exists at present, but, pending the growth of such, it may be of some interest to place together the materials which have been collected up to the present time. Altogether the dates of 13 eruptions are accurately known.

LOCALITY OF VOLCANO.	Date of Eruption.	Reference.
Near Kyauk Pyu	26th Aug. 1833	Vol. XI, p. 197.
Ditto	3-4 A.M., 23rd March 1839	Ditto.
Ditto	11 P.M., 6th Feb. 1843	Ditto.
Submarine, a little S. of False Island	7 or 8 A.M., 26th July 1843	Vol. XI, p. 198.
Submarine, S. ¾ E. from W. Barongu Island	6 or 7 P.M., 2nd Jan. 1845	Ditto.
Near Kyauk Pyu	8-45 P.M., 25th Oct. 1846	Vol. XI, p. 199.
Near Peu-lay-na, Rámri Island	7 A.M., 19th March 1878[2]	Vol. XII, p. 70.
S. of Cheduba ?	12th March 1879	Vol. XIII, p. 206.
Near centre of Cheduba	8 A.M., 27th Feb. 1881	Vol. XIV, p. 196.
South part of Cheduba	7-55 A.M., 31st Dec. 1881	Vol. XV, p. 141.
Minbyin Circle, Cheduba	23rd March 1883	Vol. XVI, p. 204.
Minbyin Circle, Cheduba (same Vol. as that of 31-12-81).	8 A.M., 28th April 1884	Vol. XVII, p. 142.
Cheduba	10th Dec. 1884	Vol. XVIII, p. 124.

[1] Vols. XI, p. 201, and XII, p. 70.

[2] There is no reason to suppose that eruptions were less frequent between 1846 and 1878 than before and after those dates, the gap being doubtless due merely to the imperfection of the record.

In the following table are given the number of eruptions that occurred in each month, and the average monthly rainfall at Kyauk Pyu (deduced from the observations of 17 years) [1] :—

	Eruptions.	Average Monthly Rainfall.
In January	1	·10
„ February	2	·06
„ March	4	·30
„ April	1	·96
„ May	0	10·12
„ June	0	41·72
„ July	1	46·62
„ August	1	39·39
„ September	0	21·23
„ October	1	10·41
„ November	0	4·19
„ December	2	·34
TOTAL	13	175·44

From this it appears that, out of an annual rainfall of 175·44 inches, 173·68 inches fall in the seven months between the beginning of May and the end of November, while only 1·76 fall in the five months between the 1st of December and end of April. Of the 13 eruptions 10 occurred during the five dry months, while only three took place during the seven wet ones. The observations, therefore, as far as they go, tend to suggest a conclusion exactly the reverse of that held by the inhabitants of the islands. It is interesting to note in this connection that (as remarked by M. Dubois de Montpéreux)[2] out of six eruptions from the mud volcanoes near the entrance to the sea of Azov, five occurred between the beginning of February and the 10th of May, or at just the time of year when the dates given seem to indicate that eruptions from the Arakán volcanoes are most frequent.

Although scarcely capable of being regarded as more than a curious coincidence, one cannot but notice the large proportion of eruptions which have occurred within an hour or two of sunrise or sunset. At night, and during the hottest hours of the day, when people are less out of doors, the chance of an eruption escaping notice is perhaps somewhat greater than at other times.

Another point attracting the attention is that, while several of the earlier eruptions took place near Kyauk Pyu, nearly all the later ones have burst forth in Cheduba, suggesting that the main focus of activity may have shifted during the last few decades. But the list is so imperfect, and so many eruptions may have escaped record, that any generalisation must be regarded with the greatest caution.

[1] Report on the meteorology of India in 1882, p. 120.
[2] Vol. XI, p. 201. Geological Observer, p. 475.

Analyses of Phosphatic Nodules *and* Rock *from* Mussooree; *by* F. R. MALLET, *Deputy Superintendent, Geological Survey of India.*

In the last volume of the Records[1] an account is given of the discovery, by the Rev. J. Parsons and Dr. Wärth, of phosphatic nodules and rock at Mussooree. Their chemical examination was taken up by my colleague Mr. E. J. Jones, who made qualitative analyses of both materials, and had commenced quantitative ones, when a severe illness obliged him to suspend the work, which he was subsequently unable to resume owing to his leaving Calcutta for work in the field. As soon after my return from furlough as other duties permitted, therefore, I submitted (12 of) the nodules and the rock to quantitative analysis, with the results given below.[2] Mr. Jones' estimations of the phosphoric acid (the only constituent he weighed) agree with those now given within one or two per cent., a result as close as could be expected from the analysis of two different samples. How far the discrepancy (in as far as the relative proportions of alumina and lime are concerned) between the composition inferred from Mr. Jones' qualitative examination, and that given below, should be ascribed to want of equality of composition in the different samples operated upon, and how far to undue reliance being placed on mere qualitative results, which circumstances prevented being checked by quantitative estimations, is perhaps open to question.

	Nodules.		Rock.	
Phosphoric anhydride	34·70	= tricalcic phosphate 75·75.	30·16	= tricalcic phosphate 65·84.
Lime	46·42		39·21	
Magnesia	·30		·55	
Alumina	3·50		5·58	
Oxide of iron			2·68	
Soluble silica	·20		·35	
Insoluble siliceous matter	9·57		16·06	
Barium sulphate				
Carbonaceous matter	·98		·92	
Loss on heating to 100C°	·32		·53	
Carbonic acid, sulphuric anhydride, fluorine, undet, and loss.	4·01		3·96	
	100·00		100·00	

The amount of carbonic acid and fluorine in the nodules is greater than in the rock, only traces of fluorine occurring in the latter. This element was not estimated separately, and only a portion is included amongst the last-mentioned constituents. There is a somewhat considerable quantity of barium sulphate in the rock, much more than in the nodules.

Both substances, and especially the nodules, are of high standard as materials for the manufacture of artificial manure.

[1] Page 198.

[2] It is unfortunate that the estimation of lime, given at page 64, which was made at a time when I was too fully occupied to undertake, or fully supervise the work, was published. The result, owing to the method employed, was not supposed to give more than a rough approximation, although, of course, the great discrepancy between the amount then obtained and that given below must be due to some error in analysis. For this, however, the operator is in no way blameable, as he was quite a beginner at such work.

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Two fossil turtles, lower eocene; one from 10 ft. below the coal at Nila, Salt Range, Punjab; and the other, from above coal outcrop at Hillanwala near Daudot, Punjab.

PRESENTED BY DR. H. WARTH.

Four specimens of fossil plants from Giridih, Bengal.

PRESENTED BY MR. J. WOOD-MASON.

Specimen of a mottled quartzite from the Kharakpur hills, Monghyr.

PRESENTED BY MR. D. MORIES, DURBHANGA.

Two specimens of native gold in calcspar, one with Malachite, said to be from one of the Khetri mines, Rajputana.

PRESENTED BY DR. J. R. STRATTON, POLITICAL AGENT, JEYPUR.

Two specimens of grindstones of Barákar sandstone, one measuring 3′ 6″ diameter and 5″ thick, and the other 10″ diameter and 2″ thick, quarried at Barákar.

PRESENTED BY THE BENGAL STONE CO. LD., HOWRAH.

A specimen of blende from Kashmir.

PRESENTED BY LIEUT.-COL. SIR OLIVER ST. JOHN, K.C.S.I., R.E., KASHMIR.

Specimens of mica, garnet, epidote, egeran, &c., from the Tonk district.

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OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1885. [August.

Notes on the Geology *of the* Andaman Islands, *by* R. D. OLDHAM, A.R.S.M. *Geological Survey of India.* (With a map.)

Geography and general features.

The Andaman Islands form a small group extending in a nearly north and south direction, between the parallels of 10° 30′ and 13° 30′ North Latitude; they, or at least the four or five northern islands, form a range of low hills which, if we look merely to the height above sea level, nowhere rise to more than 2,500 feet, but if we regard the continuation of the land slope into the sea on either side, rise to the very respectable elevation of over 9,000 feet. They are described in the report of the Andaman Committee, where it is stated that "the highest land wherever seen is on the eastern side," and that "the watershed is therefore chiefly towards the west, and consequently it is on that side of the island that the marshy localities will most probably be found." The first statement is true enough, but I very much doubt the accuracy of the second. In the South Andaman the greater part of the drainage flows into the creeks, which ultimately lead off to the eastern shore, and on the Middle and North Andaman, where the creeks are not to be found, the bulk of the drainage seems to flow through gaps in the eastern range.

Previous observers: Helfer.

2. Though the various publications, papers, and notes referring to the Andaman Islands would make a lengthy list, there are but few among them which contain any references to the geology of the Islands. The first of these, arranging them according to their dates, is to be found in the journals of Dr. J. W. Helfer,[1] who visited the islands in 1840. His journal, which is all that remains, for he was killed by the Andamanese, contains but few references to geology. He visited one of the islands

[1] Dr. Johann Wilhelm Helfer's gedruckte und ungedruckte Schriften über die Tennasserim Provinzen, den Mergui Archipel und die Andamanen-Inseln. *Mittheil. k.k. Geogr. Gesellschaft.* III pp. 166—390 (1859).

of the Archipelago (probably Outram Island) and a small island which seems to have been the Middle Button, sailed through Homfray's Strait [1] and then round the north of the island till he was killed on the east coast, either at Cadell Bay or some spot in that neighbourhood. The only geological observations refer to the Archipelago and the Middle Button, the rocks of which he classes as "Quadersandstein."

Quigley.

The next reference I can find is contained in a pamphlet by a Mr. J. H. Quigley,[2] who visited Interview Island in a schooner called the *Sea Serpent*, which had been chartered by a friend of his to recover what was worth saving from the wreck of the barque *Emily*. His account has been stigmatized by Dr. Mouat as only worthy of a Munchhausen, but, though abundantly adorned (?) with what are meant for rhetorical flourishes which, however, give place to a more moderate tone when speaking of what he actually saw, it is far more entertaining, and, as subsequent knowledge has shown, more trustworthy on the whole than the dreary pages of the learned doctor's ponderous tome. Mr. Quigley's "geological observations" are just such as a man ignorant of geology might well have made, but such as he could not possibly have invented; all that can be made of them is that the greater part of Interview Island consists of sedimentary formations, but that the extreme west (*sic* in original, probably a misprint) is composed of igneous rocks described as "granite and greenstone," terms that may safely be translated diorite and serpentine.

Andaman Committee.

The report [3] of the Committee appointed in 1857 to select a site for a penal settlement in the Andamans, contains but one single observation bearing on geology; in paragraph 41 it is stated that limestone "of the finest quality" is obtainable on a promontory a few miles north of Long Island.

Kurz.

Prefaced to a report on the vegetation of the Andamans by Dr. Kurz are some notes on the geology or more properly petrography of the South Andaman; he also gives some important observations as to the recent sinking of the islands, to which I shall refer later on.

Stoliczka.

In 1868, a short note by Dr. Stoliczka[4] was read before the Geological Institute of Vienna; being merely an extract from a private letter it does not contain any detailed observations, but refers to the general question of the correlation of the beds seen near Port Blair, to which he ascribes an eocene age.

[1] As this is, so far as I know, the only instance of these straits having been navigated by anything larger than a steam launch, it may be interesting to give the reasons on which I base this supposition; they are as follows:—(1) Sailing "north-westwards" from the Button he passed through a group of islands and found himself almost shut in by land; (2) he mentions very rapid currents in the straits; and (3) he describes the western outlet as also surrounded by islands with a very narrow passage out to the west. All these three fit in with Homfray's Straits, while none of them would be applicable to the Middle Straits (*Helfer, loc. cit.*, pp. 384—385).

[2] Wanderings in the Islands of Interview (Andaman), Little and Great Coco. *Pmpht.*, Moulmein, 1850.

[3] Selections from the Records of the Government of India, No. 25, pp. 4—28 (1859).

[4] Die Andamanen Inseln, Assam, u. s. w. (Aus einem Briefe an Herrn Director v. Haeur, de dato, Calcutta, 30th März) *Verhand. k.k, geol. Reichsanstalt.*, No. 9, p. 192 (1868).

In the Transactions of the Ethnological Society for 1869 there is a note[1] on the Andaman Islands by Lieutenant S. A. St. John, which contains some petrographical statements; he went on a trip in the S. S. *Diana* to search for limestone, and mentions the occurrence on the shore west of Long Island of what proved to be "the common igneous rock of former acquaintance," which, from its "light colour," might have been taken for limestone by one who had not landed to examine it. I cannot understand this sentence; can he have hit upon one of the pale clays, locally indurated, of the Archipelago series?

St. John.

The Proceedings of the Asiatic Society of Bengal for 1870 contain another paper[2] by Dr. Stoliczka on the Kgökkenmöddings of the Andamans which contains a passage referring to the possibility of recent changes of level in the islands.

Stoliczka.

The Journal of the same Society for that year contains two papers[3] by Mr. V. Ball on the geology of the vicinity of Port Blair and of Nancowry Harbour, in which he gives some geological details and essays to correlate the rocks of the Andaman and Nicobar Islands.

Ball.

Since this date I know of nothing further relating to the geology of the Andamans until the recent publication of two[4] notices by Mr. F. R. Mallet in the Records of the Geological Survey of India.

Mallet.

Passing now to my own observations, I can only distinguish with certainty two sedimentary formations in the Andaman Islands, which I propose to call the Port Blair and Archipelago series respectively.

Sedimentary formations.

The Port Blair series consists principally of firm grey sandstone and interbedded slaty shales, not unfrequently containing nests of coaly matter, and, occasionally, beds of conglomerate and pale grey limestone as subsidiary members. The sandstone is the characteristic rock of the series, it is generally if not always non-calcareous and is easily recognized, where exposed between tidemarks, by its peculiar mode of weathering: owing to irregular distribution of the cementing material, bosses of harder stone are left standing up above the general level of the rock, and these bosses are invariably irregularly honeycombed by the solvent action of the sea water.

Port Blair series.

[1] Notes on the Andaman Islands by Admiral Sir Edward Belcher (from notes by Lieutenant S. A. St. John, H. M.'s 60th Regiment). *Trans. Ethnol. Soc.* (*new series*), V, pp. 40—49 (1867).

[2] Note on the Kgökkenmöddings of the Andaman Islands, by Dr. F. Stoliczka. *Proc. As. Soc. Bengal*, 1870, pp. 13—23.

[3] Brief notes on the geology and on the Fauna in the neighbourhood of Nancowry Harbour, Nicobar Islands, by V. Ball, B.A., Geological Survey of India. *Journ. As. Soc., Bengal*, XXXIX, pp. 25—27 (1870). Notes on the geology of the vicinity of Port Blair, Andaman Islands, by V. Ball, B.A., Geological Survey of India. *ibid*, pp. 231—243 (1870).

[4] On Native Lead from Moulmein and Chromite from the Andaman Islands, by F. R. Mallet, Deputy Superintendent, Geological Survey of India. *Rec. G. S. I.*, Vol. XVI, 203 (1883). On some mineral resources of the Andaman Islands in the neighbourhood of Port Blair, by F. R. Mallet, Deputy Superintendent, Geological Survey of India. *Rec. G. S. I.*, Vol. XVII, pp. 79—86 (1884).

Possible older series.

In several places I found red and green jaspery beds very similar to what occur in Manipur and Burma, but I was unable to determine whether any of these belonged to an older series or no. In part at least they seem to belong to the same series as the sandstones and shales, in the midst of which they may be found cropping out, but it is by no means impossible that some of them belong to an older series, for, on the east coast of the South Andaman, close to the boundaries of the serpentine south of Shoal Bay, I found great banks of conglomerate containing pebbles of similar jaspery rock; it is of course possible that this conglomerate is newer than the sandstone, but the fact that, though found close to the serpentine it contains no pebbles of that rock, indicates that it is probably of earlier date than the serpentine intrusions, and consequently probably of the same age as the Port Blair series.

Volcanic rocks.

On Entry Island and again in a small bay, not marked on the marine chart, immediately south of Port Meadows, I found beds of volcanic origin. In the middle of the small bay just mentioned a square rock composed of a breccia of pale-green felsite cemented by a matrix of felsitic ash stands out of the water, and on Entry Island, among a series of rocks indurated and contorted so as to baffle description, there are some beds full of angular fragments, and apparently of volcanic origin. The age of these is difficult to determine; they seem to pass northwards into beds among which jaspery slate and limestone are to be found, and at the northern extremity of the island there is some intrusive serpentine, but at the southern end of the island near the top of the section, if I read it aright, I found in a bed of sandstone an isolated boulder, about a foot long, of a serpentinous rock, evidently derived from the serpentine intrusion. On the whole, it is probable that these are of later date than the Port Blair sandstones.

Chatham Island.

Before passing on to the next series, I must mention one very peculiar rock which is exposed on Chatham Island, and which I have not seen elsewhere. On the south shore of the island, immediately east of the saw-mill, there is an exposure of sandstone, through which are scattered blocks of red and green slatey rock; these, as is shown by their angular outline and lamination, quite independent of, and divergent from that of the sandstone matrix, are evidently fragments of some pre-existing rock. It is difficult to explain their presence here; in the absence of any signs of volcanic action in the immediate neighbourhood, one would naturally turn to glacial agency; yet the apparently isolated nature of the phenomenon is against this explanation, while the fragments are too numerous, and scattered over too large a surface, for them to be satisfactorily explained by any theory of flotation by driftwood.[1]

Archipelago series.

The newer series, which I have called the Archipelago series, as the whole of the islands of the Archipelago are formed by it, consists typically of soft limestones formed of coral and shell-sand, soft calcareous sandstones and soft white clays, with occasionally a band of conglomerate the pebbles of which seem originally to have been coral, though no structure is now discernible. These beds seem to cover a large area in the

[1] *Confer* Theobald's description of some beds belonging to the axial (triassic) group. *Mem. G. S. I.*, Vol. X., p. 127 (1873).

Andamans, but I shall not here enter into the discussion of their geographical distribution.

Sandstones of Craggy Island.

On Craggy Island, I found a somewhat peculiar rock; it was a soft bedded very calcareous sandstone; the calcareous cement was irregularly distributed, forming spheroidal masses of harder rock which stood out from the general surface of the cliff, and this, combined with strings of small pebbles scattered through the beds, gave the rock an appearance very much resembling that of many of the Siwalik sandstones. Some of the pebbles were of serpentine, so that the rock is almost certainly of later date than the Port Blair series, yet it may be remarked that where exposed between tide marks, the projecting bosses weather away in a manner which feebly imitates the honeycombing of the very much more prominent knobs to be seen at Port Blair.

And south of Port Meadows.

There is only one other place where I have seen a similar rock in the Andamans, and that was on a rocky point a short way south of Port Meadows. I did not here notice any serpentine pebbles, but the position of the rock would lead one to associate it with the volcanic beds which, as I have mentioned above, are probably of more recent age than the Port Blair series. It is not impossible that the sandstones just referred to may belong to the Archipelago series.

Cinque Islands.

The Cinque Islands consist principally of intrusive rock of the serpentine series, but there are also some metamorphosed and indurated sedimentary beds; of these some are siliceous, but for the most part they are calcareous, the most remarkable form being a green chloritic or serpentinous matrix with numerous granules of crystalline calcite scattered through it; the rounded outlines of these granules seem to be due to attrition, and the crystalline structure to subsequent metamorphism. These rocks did not seem to me to belong to the Port Blair, but to the Archipelago, series, and at the first blush it would seem as if they had been metamorphosed by the intrusion of the serpentine; fortunately however at one or two places, and more especially on the eastern face of the southern island close to its northern end, there are exposures of a conglomeratic bed, in which the pebbles are of serpentine, and the matrix is fine-grained and very serpentinous. This conglomerate, both from its position and induration, belongs to the same series as the other sedimentary rocks of the island, and proves that they are of later date than the serpentine intrusion, and that in all probability their metamorphism is due to the contortion they have locally undergone. The conglomerate just mentioned is a curious bed, not of the type commonly known as conglomerate, but exhibits that structure, usually considered due to the action of floating ice, which is seen in the boulder bed of the Talchirs, or the Blaini conglomerate of the Himalayas. The matrix is, or rather was originally, a fine mud or clay, and through it the pebbles are scattered, not touching each other, but each isolated in the matrix; I have seen a similar bed of presumably the same age, though showing no signs of alteration, in a very similar position to the east of the Nijaong village in the harbour of Nancowry, but here the fragments were angular, not, as on the Cinque, rounded in outline.

Intrusive rocks.

As regards the intrusive rocks of the Andamans I have little to say; they are similar to those of Manipur and Burma to the north and of the Nicobars to the south, and, as far as I could judge from the manner of their occurrence, of certainly later date than the Port Blair series, the only section which seems to throw any doubt on this conclusion being that described above of the sandstones on Craggy Island. I have followed my predecessors in calling these rocks serpentine, that being the most prominent or remarkable form which they take, but they not infrequently pass into crystalline diorite or gabbro.

Two distinct formations.

It may seem strange that, before passing on to consider the correlation of these series, it should be necessary to discuss whether they really belong to distinct formations, or are merely local petrological variations of each other, but, as will presently be seen, such is the case. As regards the Andamans, I have no doubt that they are really two distinct formations, for in degree of induration and mineralogical composition they are as contrasting as could well be, nor have I seen any signs of transition from one type to the other (if we except the sandstones of Craggy Island) and in the Middle Andaman, where I saw the soft limestones of the Archipelago, and the hard grey sandstones of the Port Blair series within a few miles of each other; they each maintained their especial characteristics unchanged. While if my identification of the altered sedimentary rocks of the Cinque Islands with the Archipelago series is correct, they must be two distinct formations, one older, the other newer, than the serpentine intrusions.

Homotaxis of the beds.

In investigating the homotaxis of these beds, we may approach the question from three points of view, and determine the age of the beds either by the internal evidence of fossils, by connecting them with the known rocks of the Arracan Yoma, or by connecting them, through the Nicobars, with beds of known age in Java.

Fossils.

As regards the first, we have nothing beyond Dr. Stoliczka's statement[1] that he observed "at the north-east end of Ross Island several specimens of a Pecten, a small Cytherea-like shell, and fragments of Oysters, which fossils prove that the deposits are marine, and the aspect of these fossils is undoubtedly a tertiary one." I regret to have to say that though I searched the locality mentioned, I did not succeed in finding, either there or elsewhere, any trace of a fossil other than a few fragments of lignite.

Relations with the Nicobar beds.

In attempting to ascertain the age of the Andaman rocks by tracing them southwards through the Nicobars, we are at once landed into a difficulty through a conflict of authorities.[2]

[1] *Journ. As. Soc., Beng.*, XXXIX, p. 231 (*footnote*), 1870.

[2] Die Nicobarischen Inseln. Eine geographische Skizze, mit specieller Berücksichtung der Geognosie von *Dr. Phil. H. Rink.* Kopenhagen, 1847. *Translated and printed in* Selections from the Records of the Government of India, LXXVII, pp. 109-153.

Beiträge zur Geologie und physickalischen Geographie der Nicobar Inseln.—Geologischen Beobachtungen von Dr. Ferdinand von Hochstetter. Reise der österreichischen Fregatte Novara um die Erde in den Jahren 1857, 1858, 1859. Geologischer Theil, II, pp. 85—112 (Wien. 1866). *Translated and printed (in part), Rec. G. S. I.*, IV, pp. 59—73 (1870). *Reprinted* Selections from the Records of the Government of India, LXXVII, pp. 208—229.

For our information as to the rocks of the Nicobars, we have to rely almost entirely on the published papers by Drs. Rink and Hochstetter. The former of these describes the rocks of the Nicobars as belonging to three distinct formations, classed in order of their ages as (1) the brown coal formation; (2) the Plutonic rocks*; (3) the older alluvium. The brown coal formation is confined to Katchal and the southern islands, while the "older alluvium" is only found on the islands of Nancowry, Trinkat, Camorta, and those to the north. Dr. F. von Hoschstetter, on the other hand, maintains that the "brown-coal formation" and the "older alluvium" of Rink are but petrologically different products of the same period of deposition, and that they are both of later date than the serpentine intrusions.

In his note on the geology of the neighbourhood of Nancowry harbour,[1] Mr. V. Ball states it as his opinion, that the sandstones of Rink are the same as those of Port Blair, but does not attempt to decide between the widely divergent opinions of Rink and Hochstetter.

"Older alluvium" of Rink represents Archipelago series.

In discussing this subject I may begin by stating it as my opinion, derived from personal examination of both, that the "Older alluvium" of Rink, and my Archipelago series, are most indubitably of the same age. As Mr. Ball has pointed out, Rink's name is utterly inappropriate if the word alluvium is to have any fixed value whatever in geology; the beds of which it is composed have been contorted and disturbed, and occasionally may be seen tilted on end. They are undoubtedly of later date than the serpentine intrusion, and agree very closely in petrographical characters with those of the Andaman Archipelago, even to the occurrence of clays containing polycistinoe in both regions and of iron sand on the Car-Nicobar, while iron sand was noticed by Dr. Helfer on the Middle Andaman, and is also found on Havelock Island.[2]

Difficulty regarding the sandstones.

As regards the sandstones, the matter is not so easily settled; if Dr. Rink has correctly determined the relative ages of the sandstones and the serpentine intrusions, Dr. Hochstetter must necessarily be mistaken in supposing that they are merely petrographically different members of the same series as the soft calcareous and argillaceous beds of the so-called older alluvium. The only direct evidence which Dr. Rink adduces as to the relative ages of the sandstones and the serpentine series is a section[3] on the western side of Teressa Island, where he saw a small patch of the sandstone, of the same type as that of the southern islands, only slightly hardened by the plutonic rocks which form veins in it. Here everything depends on the correctness of the correlation of this sandstone with that of the southern islands, a correlation which is certainly supported by Mr. Ball's identification of the latter with the sandstones of Port Blair. The latter observer gives no reasons, beyond the presence of fragments of driftwood and impressions of

[1] Brief notes on the Geology and on the Fauna in the neighbourhood of Nancowry Harbour, Nicobar Islands, by V. Ball, B.A., Geol. Surv. of India. *Journ. As. Soc., Beng.*, XXXIX, pp. 25—37.

[2] In the first and last case, and presumably in the second also, the so-called "iron sand" was magnetic oxide of iron; for a reference to the Havelock Island sand, see *Rec. G. S. I.*, Vol. XVIII, 83 (1884).

[3] Die Nikobarischen Inseln, p. 56. Selections from the Records of the Government of India, LXXVII, p. 130.

plants resembling fucoids in both, for the identification, though it was presumably based on personal observation. On the other hand, there are not wanting indications that both these observers may have been mistaken, for Dr. Rink's description of the sandstones of the Little Nicobar, which he takes as the typical exposure is certainly very unlike that of any beds I know in the Port Blair series; he describes [1] both sandstones and interbedded clays as calcareous, and particularly mentions that the former were soft, and that the calcareous matter is irregularly distributed, forming spheroidal masses of harder rock which are left projecting from the general surface of the cliff—in fact the description agrees in every particular, except the absence of pebbles, with the sandstones on Craggy Island, in which I found pebbles of serpentine and which are consequently almost certainly of later date than the Port Blair sandstones. The whole question is shrouded in difficulty and will not be answered satisfactorily without a systematic survey of the islands.

Relations of Andaman and Javan beds.

Passing southwards into Java and Sumatra, there are intrusive serpentine and soft white clays identical with those of the Nicobars. Dr. Hochstetter [2] describes the sedimentary series of Java as consisting of (1) a lower coal-bearing group of quartzose non-calcareous sandstones and slate clay with seams of workable coal, in which marine fossils are very rare or absent; (2) an upper group of soft calcareous sandstones, plastic clay slates, and argillaceous marls with trachytic tufas conglomerate and breccias, containing numerous marine fossils and fragments of drift wood, but no workable coal. These rocks were originally classed by Hochstetter [3] as eocene, on account of the supposed discovery of nummulites in them, but according to Von Richthofen, [4] the so-called nummulites are in reality orbitolites, and a collection of fossils from the upper beds was examined by Mr. Jenkins, [5] who pronounced them to be of miocene, or later age. The lower series may be distinct from the upper, and of eocene age as Dr. Hochstetter supposes, and in that case is very likely a representative of the Port Blair series.

Relations of Andaman and Arracan beds.

In tracing the Andaman rocks northwards to Burma, we have little difficulty in identifying the Port Blair series with the Negrais rocks of Theobald.[6] Not only do they resemble each other in the petrographical features and relative proportions of

[1] Die Nikobarischen Inseln, p. 43. Selections from the Records of the Government of India, LXXVII, p. 126.

[2] Geologische Ausflüge auf Java. Reise der österreischen Fregatte Novara um die Erde in den Jahren 1857, 1858. 1859, Geologischer Theil Band II. Geologische Beobachtungen von Dr. Ferdinand von Hochstetter, pp. 113—152 (Wien 1866).

[3] Nachrichten über die Wirksamkeit der Ingenieure für des Bergwesen in Neiderländisch—Indien. Von Dr. Ferdinand Hochstetter. *Jahrbuch. K. K. Geol. Reichsanstalt* IX, pp. 277—294 (1858).

[4] Bericht über einen Ausflug in Java. *Zeitschrift der Deutschen Geol. Gesellschaft* XIV, pp. 327—356, 1862.

Über das Vorkommen von Nummulitenformation auf Japan und den Phillipinen. *Ibid.* 357—368.

[5] On some Tertiary Mollusca from Mount Sela in the Island of Java, by H. M. Jenkins, Esq., F. G. S., with a description of a new coral from the same locality, and a note on the Scindian fossil corals by P. Martin Duncan, M. B., F. G. S. *Quart. Journ., Geol. Soc.*, XX, pp. 45—73 (1864).

[6] *Mem. G. S I.*, Vol. X, 110—123 (1873).

their individual members, but the peculiar mode of weathering where exposed between tide marks, which I have remarked in the former, is matched by the sandstones of the Negrais group, which have been described as usually presenting, when seen on the sea beach, a—" honeycombed or cancellated appearance, the result of a peculiar mode of weathering."[1] Unfortunately the age of the Negrais rocks cannot be determined with accuracy, but they are believed to underlie and be associated with some beds of known nummulitic age, so that we may class the Port Blair rocks as eocene or slightly older.

General conclusion.

Thus, whatever line we follow, we are brought up to the same conclusion, *viz.*, that the Port Blair series is probably of early tertiary, or possibly late cretaceous age, and by tracing them southwards, we find that the rocks of the Archipelago series are probably of miocene age or even newer.

Changes of level.

Since the publication of Kurz's Report on the vegetation of the Andamans, it has been an accepted fact that the Andaman Islands are, and have been, during recent times, undergoing subsidence. It was difficult to conceive how this could be the case, for the Arracan coast to the north and the Nicobar Islands to the south, between which the Andamans form the connecting link, are both fringed by raised beaches which show that they have recently been elevated, but the observations recorded by Mr. Kurz were so unanswerable that they were allowed to override the argument from analogy. Mr. Kurz's conclusions were based principally on the fact that he found the stumps of trees, belonging to species which only grow above high-water mark and beyond the reach of salt-water, in the mangrove swamps and on the sea shore, while, as corroborative evidence, he adduces the facts that according to the report of the Andaman Committee the sea had encroached some 40 or 50 feet since the first settlement on Chatham Island, Port Cornwallis, and that " Lieutenant Jameson of Chatham Island has informed me that a similar encroachment of the sea is taking place at that Island in Port Blair." As regards the latter point, there is no evidence that the "encroachment" of the sea at Port Cornwallis was due to subsidence, and as far as can be judged by the lithograph in the report of the Andaman Committee, and the woodcut in Dr. Mouat's book, both taken from a photograph, I should be inclined to look upon it as a case of encroachment by erosion of the sea shore and not by subsidence. The evidence of the trees is, however, almost conclusive, for the only explanation possible, apart from an outward set of the soil towards the sea, such as is known to take place under certain circumstances, is that the land is sinking, and I can myself produce an observation which supports this conclusion. The large bay on the north-east coast of Havelock Island is for the most part fringed with low lying land, next to the beach this rises some 4 or 5 feet above high-water mark, but in many places behind this it sinks to form a hollow, and then rises again to the same level as the outer ridge, or rather higher. The whole of this low land is covered with forest, but wherever there is one of the hollows just mentioned, there the forest trees are all dead, and the soil is often moist with salt-water; the soil of these low lying patches must have once

Evidence of depression.

[1] *Loc. cit.*, p. 117.

been dry, like that where the forest is still growing, and the uniformity in size of the dead and the living trees shows that in all probability several generations have lived and died on rise and in hollow alike, until, as the land gradually subsided, the sea-water rose in the soil of the hollows and the trees succumbed to its fatal influence.

Raised beaches, South Andaman.

We may therefore take it as proved that the Andamans are at the present day gradually sinking, but there is ample evidence in the raised beaches that fringe the shores of the Andamans, that in the immediate past elevation has exceeded subsidence. These raised beaches have not, so far as I know, been mentioned by any previous observer, but are conspicuous enough, especially on the islands of the Archipelago. At Port Blair itself there is a small terrace at the north-eastern corner of Chatham Island; it has been enlarged artificially to form a site for the bungalow of the officer in charge of the island, but appears to be in part a raised terrace of marine erosion. A similar terrace may be seen north of the harbour where the road from North Point to North Corbyn's Cove runs in places on a terrace separating the steep hill side from the sea shore. In a small cove east of Perij, on the southern side of Shoal Bay, there is a narrow terrace, clothed with forest, from whose inner limit the hill rises in a bare, almost vertical, face of rock which could not have been formed, in this position at least, by any other means than marine denudation. Along the east coast of the South Andaman this raised beach can be seen forming a terrace, from a few yards to over half a mile in width in almost every bay. Apart from the theory that it is raised sea beach, the only one supposition on which this terrace could be accounted for is, that it is due to a gradual encroachment of the land on the sea, either through the action of vegetation in catching the wind-blown sand, and so raising the surface above extreme sea-level, or by the action of the waves which during storms might throw up sand and shingle far above the level which the sea would otherwise reach; the first supposition is inconsistent with the fact that shells and fragments of coral of considerable size may be found lying about on the forest-clad surface of the terraces in positions where they cannot be accounted for by either human or crustacean agency, while the facts that the forest trees are as large and old on the extreme edge of the terrace as further inland, and that the seaward margin often cuts into a miniature cliff of 3 or 4 feet high, is everywhere fringed with fallen and falling trees and tangles of roots from which the soil has been washed away, conclusively prove that so far from there being any extension of the land surface, it is being encroached upon by the destructive action of the waves.

Archipelago. Havelock Island.

The terrace is well developed in the Andaman Archipelago, especially on the west coast of Havelock Island, where the hills rise with a precipitous face out of the forest, being now separated from the sea by a stretch of dry land; but at one place, where the sea has cut away this terrace and formed a low cliff, a bank of coral and shingle, evidently of littoral origin, was seen resting on soft calcareous sandstone, well above the reach of even the highest tides.

Outram and Lawrence Islands.

The beach I have described is everywhere low, and not more than 6 to 8 feet above mean sea-level, but there are indications of a terrace of marine erosion, corresponding to that seen on the Car-Nicobar and elsewhere at about 30—40 feet above the sea;

both Outram and Lawrence Islands, and a large part of the other islands of the Archipelago, are low and flat-topped in outline, so that it would seem that they were plateaux—old plains of marine denudation.

Commencement of depression being of recent date.

There is not wanting evidence that the depression of the island, which is going on at the present time, has but recently commenced, for the kitchen-middens of the Andamanese are in positions where a very slight subsidence would submerge them, and the time that they represent may be understood by the section of one which I examined near Port Mouat; it was 12 feet in thickness in the centre, and in this there was a bed 1 foot 6 inches thick of vegetable mould, with shells scattered through it, marking a period when generations of shrubs and plants must have lived and died while the midden was abandoned, or only occasionally visited. This was doubtless started on a rock rising among the mangroves and gradually extended on to the mud; and it is a noteworthy fact that the surface of the mud under the shells does not appreciably differ from the general level of the mud outside. It shows that at a time when probably not one-sixteenth of the present bulk of the midden had accumulated, the level of the mangrove swamps was very nearly what is now. Had the soil surrounding the rock on which the midden was started been well clear of the influence of the tides, it would certainly not have supported a growth of mangrove, and so far as my experience has shown me, would consequently have been of a very different character to what is actually found, while, had the surface of the mangrove swamp stood much lower than what it now is, the mud would certainly have risen above what was the base of the kitchen-midden in its earlier stages; in other words the surface of the mangrove swamp was then very nearly at the highest level it could reach, and as this is limited by the height to which the tides rise, it shows that during the time represented by the formation of this midden—a period which must be measured by centuries, if not by tens of centuries—the land has not appreciably altered its level relatively to the sea.

NOTE.—On the map, I have incorporated Mr. Kurz's observations in part, but have not followed his maps in extending the Port Blair sandstones to the western shore of the Islands, as I feel sure that the rocks there must be largely of later date; I have coloured the islands off the two entrances to Homfray's Straits from information derived from Dr. Helfer's Diaries. Interview Island, I was informed by Mr. H. Godwin-Austen, is composed of the same rocks as are seen at Nancowry, and the two Sentinel islands have been described to me as being composed of coral; this, as I found from experience in the Nicobar Islands, almost certainly refers to the fantastical weathering of the limestones of the Archipelago series.

Note on a third species of Merycopotamus, *by* R. LYDEKKER, B.A., F.G.S., F.Z.S.

Among the collection presented to the British Museum by Mr. Charles Falconer on the death of Dr. Falconer, the writer has recently identified the tooth from Kushálgarh near Attock noticed in 'Falconer's Palæontological Memoirs,' Vol. I, p. 416, under the name of *Merycopotamus nanus*, and also the two smaller teeth noticed on the preceding page under the name of *Tapirus pentapotamiæ*. As these specimens are undoubtedly the property of the Geological Survey of India,

the Director of the British Museum has consented to their transference to the Indian Museum.

With regard to the *Merycopotamus* tooth, which is the third right upper true molar, there can be no doubt of its specific distinctness from *M. dissimilis* and *M. nanus*, Lydekker,[1] both on account of its inferior size, and marked difference in structure. Its length is 0·75, and its width 0·8 inch; and the external surface of the outer columns is less inwardly inclined, thus causing the tooth to assume a character more approaching that of *Chæromeryx*, which the writer[2] is now inclined to regard as allied to *Dichodon:* the present specimen thus indicating an affinity between the latter and *Merycopotamus*. It is intended to figure the Kushálgarh *Merycopotamus* tooth in the Introduction to the 3rd volume of the 10th series of the 'Palæontologia Indica'; and the specific name *M. pusillus* is proposed for it.

The two small teeth noticed by Falconer as *Tapirus pentapotamiæ* are the fourth upper premolars of both sides belonging to the same individual as the upper true molar noticed by Falconer in the same passage and figured by the present writer in the 'Palæontologia Indica,' ser. 10, Vol. III, pl. VIII, fig. 17, under the name of *Listriodon pentapotamiæ* (Falc.).

Some observations on Percolation *as affected by* Current, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

In a previous paper (*supra*, XIV, p. 228), in discussing the possible water-head available for artesian sources in the Gangetic plains, I quoted an observation by Lieutenant W. E. Baker (one of the early collectors of Siwalik fossils, afterwards Sir W. E. Baker), showing a striking apparent defect of percolation in very coarse deposits close to a great stream. The passage is as follows:—"An account is given by Lieutenant W. E. Baker (Engineers) of the sinking of a well at Ráyanwála, near the base of the Siwaliks. It is 3 miles below Hátnikúnd, where the deposits terminate within the open gorge of the river, but the elevation is still 1,052 feet. The surface is less than 10 feet over the water in the river, and only 60 yards from the edge, but the well was sunk through boulders gravel and sand for 60 feet without finding water. Lieutenant Baker mentions the fact as an anomalous instance of the impermeability of the coarse river deposits at this spot, contrasting it with what takes place in similar deposits of the *bhábar* east of the Ganges, as already noticed. This is of course an erroneous impression: there is a deep and rapid current in the Jumna at Ráyanwála, and the traction of the stream does not give any particle of the water time to change its course and sink into the ground. The case is very different for small streams spreading out over the surface."

[1] 'Geol. Mag.' dec. 3, Vol. I, p. 545 (1884). The name *M. nanus* had been applied by Falconer in M.S. (*vide Pal. Mem.*, Vol. II, p. 407) to this species, before he applied it to the Kushálgarh specimen, which he evidently regarded as distinct. When the collection of Kushálgarh specimens were returned to India, a label bearing the name *M. nanus* was attached to a tooth referred to *Dorcatherium* (*vide* 'Palæontologia Indica,' ser. 10, Vol. I, p. 62 [44],) and the present writer naturally thought that Falconer had made a wrong generic identification.

[2] *Vide* 'Geol. Mag.' dec. 3, Vol. II, pp. 72—73 (1885).

Several friends who ought to know, expressed doubts that the reason her egiven by me was in any degree valid; so not being able to find an authority on the subject, I have attempted an appeal to experiment, with Mr. Mallet's assistance. In the bottom of a small wooden conduit, about 5 feet long, a rectangular hole was cut, 3 inches long by 1 inch broad. This was lined with sheet-tin, projecting below into a much larger tin box attached to the board, with openings along its upper margin for the escape of water. The hole was then packed with shot, flush with the bottom of the conduit, and up to the level of the openings in the box beneath. Arrangements were made to give a succession of fixed slopes to the conduit, and to measure the discharge from percolation in equal periods under the different conditions. From still water with a depth of about 1 inch the percolation was 1,045 grammes in 30 seconds. The comparative results are given in the following table:—

Statement showing percolation as affected by current.

Percolation.	Conditions.
1,000	Still water: end of conduit closed.
900	Conduit horizontal, end open.
806	„ sloping at 25 feet in a mile.
783	„ „ „ 50 „ „ „
770	„ „ „ 75 „ „ „
747	„ „ „ 100 „ „ „
729	„ „ „ 125 „ „ „

The experiments were no doubt rough, but it can hardly be questioned that they give a true indication of what occurs, showing very decided reduction of percolation with increase of current. The loss is nearly 20 per cent. with a slope of 25 feet to the mile, which is about that of the stream at Ráyanwála. Although, however, the interpretation I gave of the supposed anomaly is thus shown to have but partial application, the main cause must be rather the reverse of that suggested by Lieutenant Baker. We must assimilate, rather than contrast, the conditions at Ráyanwála with those of the *bhábar* streams. The percolation downwards is so free and rapid that laterally it does not extend to a distance of 170 feet at a depth of 50 feet below the level of the stream; and the slope of percolation must be more than 1 in 3·4.

In support of this view I may refer to the instance given in the same paragraph of the paper under reference, of a well at the head of the *bhábar*, near Mohan. Although within a short distance of the Kotri *rau* (torrent), all the dry-weather drainage of which sinks into the gravel, water was only found in the well at a depth of 200 feet.

Notice of the Pirthalla *and* Chandpur Meteorites, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

In 1863 a requisition from the British Museum, respecting the collection of aerolites which may be procurable in the British dominions abroad, was forwarded by the Secretary of State for India to the Government of India, and was issued by it to the Provincial Governments for disposal. On the representation of Dr. Oldham in 1866, that this order was liable to be misunderstood, to the detriment of the very fine collection of meteorites in Calcutta, the Governor General in Council was pleased to approve, for general adoption, the recommendation that all meteorites should be sent to the Calcutta Museum, and suitable samples be forwarded thence to the British Museum. During the twelve years following this order, up to the end of 1878, specimens more or less complete of 11 falls were received, and samples of all were duly sent to London. For years after none were seen or heard of till 1884, when official notice came of the Pirthalla fall, but without any hint of compliance with the order regarding the disposal of such objects, although it was of course still in force. It was plain that the rule had passed out of recollection, as is so generally the case in India with matters that are not of almost routine occurrence, owing to the so frequent changes in the personnel of every office. A renewal of the order was therefore sought for and obtained, of which these two meteorites are the first-fruits.

Pirthalla: No. 189 *of the Indian Museum collection.*—This is a village in the Barwala tahsil of the Hissar District in the Punjab, in about 29° East Longitude and 29° 35′ North Latitude. The fall occurred at 2 P.M. on the 9th of February 1884. The stone was received in three pieces, and otherwise damaged, having lost perhaps an eighth of its original bulk. The pieces weighed severally 510·6, 425·7, and 224·2 grammes, or a total of 1160·5 grammes. The specific gravity is 3·40. The shape was roughly cuboidal with rounded edges and indented sides. The stone is of the most usual type, granular fracture, of light-grey colour, mottled pale brown. The numerous metallic grains of various size and shape only appear on a cut surface, being otherwise covered by a coating of the stony substance. This stone is rather friable. There is of course the usual film of fusion, of a dull black colour. The account of the fall received with the specimen is as follows:—

"The history of the meteorite briefly is, that it was seen to fall at 2 P.M., on the 9th February 1884, about 150 paces from the village of Pirthalla, P.S. Tohana, Hissar Division, by a sepoy on the Skinner estate and a boy of 12 years of age. It seems to have been red-hot when falling, and an explosion was heard while it was still in the air, which was followed by a report like that of a gun when it struck the earth, in which it was buried to the depth of 2½ inches. The ground was hard. It was dug up immediately, and is said to have been quite cold and broken in two."

Chandpur: No. 190 *of the Indian Museum collection.*—This is a village in the North-West Provinces, about 5 miles north-by-west of Mainpuri, in 79° 3′ East Longitude and 27° 17′ North Latitude. The fall occurred on the evening

of the 6th April 1885. The stone was received unbroken, though about one-fourth of the crust, and perhaps a twelfth of the original bulk, had been chipped off. The shape was roughly cuboidal with rounded edges and angles. Before cutting, the weight was 1201·3 grammes; the pieces weigh 625·5 and 491·0 grammes. The specific gravity is 3·25. It is exactly of the same type as the Pirthalla stone, but not so brittle. The following is a translation of the report of the fall by the Native Sub-Inspector of Police:—

"On 10th April, Girdhari Chaukidar, of mouzah Chandpur, which is 8 miles south of the police station, came and reported that four days ago, on the night of Monday, there was thunder and lightning which lit up the whole sky, and after this a stone came down, which was found next morning and weighed 1 seer and 4 chittacks. I deputed Mahomed Hussan Khan, clerk, to fetch the stone and make full enquiry into the matter. The clerk accordingly brought the stone to the thana. Its surface is black. It is white inside, containing shining particles like those of sand. It is broken on two sides, which is due to the fact that the villagers broke it to see what was inside before the clerk reached the spot. The pieces broken off could not be found. Enquiry made by the clerk showed that on Monday, about one-and-half hour after night-fall, heavy clouds came over mouzah Chandpur; that Telok Singh Thakur and Bhagga and Manga Chamars were busy in stacking arhar stalks in a field about 100 paces south-east of the village, and that they first saw lightning in the clouds and then heard a roaring thrice; that afterwards it thundered slowly and then of a sudden the whole sky was lit up and a sound of something coming down (sam same) was heard, and subsequently the sound of a thud in the arhar field of Madariwala, which is one field beyond their own; that they then ran away to their respective houses fearing that hail was falling. As the whole affair was one of a surprising kind, they, on Tuesday morning, wanted to find out what it was, and on search, found the stone produced in Madari's field; that it was still warm, and the earth below it was blackened, and a plant of arhar, on which it had fallen, was scorched and broken down, but that no mischief was caused to other plants in the field. Other villagers also testified to these facts. I beg to forward the stone for your inspection."

Report on the Oil-Wells *and* Coal *in the* Thayetmyo District, *British Burma, by* R. ROMANIS, D. Sc.

Oil-Wells.—The oil-wells are at Padaukpin,[1] about 8 miles from Thayetmyo, on the Mindôn road. Of seven wells there are only three kept in repair, and of these only one was yielding oil at the time of my visit. The oil flows very slowly; the produce is only one barrel monthly. It occurs in fissures in a hard blue shale (dipping 35° W.), which contains fossil marine shells, which are generally much decomposed by the action of water; often there is only the cast of the shell in the clay remaining.

At Yenanchaung, in Upper Burma, the oil-bearing stratum is a similar blue shale with bands of sand, into which the oil diffuses from the shale and through

[1] Noticed by Mr. Theobald, *Mem., G. S. I.*, Vol. X, p. 347 (1873).

which it percolates into the wells. The shale at Padaukpin seems almost impervious. I observed a place where the shale cropped up to the surface. It was converted superficially into clay by the action of water. The oil was found lining small cracks and cavities. When a piece of the shale was powdered and diffused through water the oil came to the surface in a thin film.

A specimen of the shale was analysed and found to contain 0·16 per cent. of oil.

The rocks overlying the oil-bearing stratum appear much harder than those at Yenanchaung. It appears to be a different geological formation, deposited under different conditions. A boring was put down to a great depth some years ago in one of the ravines to the northward. It ended in hard rock, without finding oil. I do not know why the place in question was selected; the whole district is very unpromising.

Coal.—The coal is found in a ravine of the south-western spur of the second or middle hill of the group of lime-hills south of Thayetmyo.[1]

When I visited the place, an escarpment had been made along the east side of the gorge; at the north end a drift had been driven into the hill side through a hard blue shale to a depth of about 20 feet; at the end of the drift there was a thin seam of coal and carbonaceous shale dipping at an angle of about 30°. Below this another drift had been made, but had fallen in. The seam of coal is said to be 4 feet thick. Further south, again, a pit had been sunk to a depth of 30 feet, following the course of the two small seams of coal here dipping at an angle of 75° to 80°. They are 4 feet apart at the top, but gradually approach and will unite probably 3 or 4 feet lower. Five or six yards further south there are seen two more vertical beds of carbonaceous shale. One of these is said to be the seam worked about 30 years ago. The traces of the old workings are now concealed under the rubbish thrown down from the escarpment above. The old drift is said to be vertically below the lime kiln on the hill side.

The blue shale below the coal is full of vegetable remains, apparently grasses or reeds. Above the coal the shales appear to be unfossiliferous. Over the shales are sandstones. Above these, again, there is a greyish-pink limestone; then over all, forming the crest of the hill, is a white limestone composed of fossil nummulites and marine mollusca.

It seems to me that the coal deposits of the Arakan Yoma have been formed in the swamps and lagoons of a river delta. We find similar deposits of very recent date in the neighbourhood of Rangoon. Thus, at Insein, a boring showed a thin bed of lignite. Beneath the alluvial soil on which part of the town of Rangoon stands, there is a stratum of decomposed vegetable matter about 2 feet thick, thinning out and disappearing where it meets the sandstones, on which the cantonment stands. Above this stratum there is a fine blue clay; above the clay is the sandy clay of the rice-fields. We have the same order at each of the coal outcrops in Burma,—argillaceous sandstones, blue shade, coal.

At Thayetmyo the deposits have evidently been formed while the land was

[1] Described by Dr. Oldham, Selections from the Records of the Government of India, Home Department, No. X, 1856; also by Mr. Theobald, *Mem., G. S. I*, Vol. X, p. 295 (1872).

slowly sinking beneath the sea, the limestones overlaying the shales and sandstones having been deposited on a sea bottom, when the head of the Gulf of Martaban was at Yenanchaung or Sagaing. The sudden change in the angle of dip shows that there has been a great disturbance of the strata.

It seems to me that the coal worked 30 years ago was a portion of the present 4 feet seam, and that a fault runs between the main hill and the southern spurs; but Mr. Lewis, who is carrying on the work, seems to think that the old drift was driven in the wrong direction, and that he will find the seam at the bottom of the pit he is sinking. On this theory there should be two seams 4 feet thick, separated by 60 or 70 feet of shale. The question should be settled in a few days.[1]

It is noteworthy that a similar nummulitic coal-field by the banks of the Indus has just been carefully tested by boring and found to be so irregular as to be worthless.[2]

A series of specimens illustrating the rocks at the Padaukpin and Yenanchaung oil-wells and the coal-mine at the lime hill has been placed in the Phayre Museum.

1st January 1885.

Note on some Antimony Deposits *in the* Maulmain District, *by* W. R. CRIPER, A.R.S.M., F.C.S.

From Maulmain a range of hills, called the Toungwayn, Toungmyo, or Amherst range, runs in a south-easterly direction through the province of Tenasserim. The following remarks apply to that part of the range between Maulmain and Amherst, a distance of about 50 miles. The range is densely covered with jungle, and is inhabited by a few Karens; a good road runs along its base.

These hills are mainly composed of a hard siliceous slate, the strata of which are more or less disturbed, but with a general direction of north-west south-east and a nearly vertical dip; mica schists also occur. Overlying both are soft sandstones more or less horizontal, accompanied by quartzose rocks, while along the flanks and in the plains below, superficial deposits of laterite are occasionally met with.

Limestone does not appear to exist in this range, but isolated hills or rather peaks are found near, which are rapidly disappearing through atmospheric denudation. The existing hills show the power of this influence in their worn sides and sharp angular peaks.

The minerals occurring in the range of hills under consideration are iron ores and antimony. The iron ores might be of use should coal, good enough to smelt them, ever be found within a reasonable distance, and English competition cease.

[1] From recent information dated 22nd June, it would seem that the expected coal has not been found. The Agent of the Murray Coal Company is, however, persevering with the exploration.—H. B. M.

[2] *Supra*, Vol. XVII, Pt. 2.

As long ago as 1860, attempts were made at Toungwayn, near Maulmain, to work the antimony found there, in a hill called Tæ-læ-toung (antimony hill), but without success, the reason given being that the market value of the ore in Calcutta was too low. Other trials have been made since then, invariably with a like result.

The antimony is in the form of stibnite and occasionally cervantite. This latter mineral, which always occurs above the stibnite and is probably due to its oxidation, was not known to the Burmese until pointed out to some of them recently by me, it having too great a resemblance to yellow earth to be noticed by them. They are however well acquainted with stibnite, under the name of Tæ-læ-chouk (antimony stone) or Tæ-læ-byn (white antimony). The cervantite has obtained the name of Tæ-læ-wa (yellow antimony).

The stibnite occurs in pockets, or isolated masses in a whitish quartzose sandstone, the rock in the immediate neighbourhood being often stained of a bluish colour by the antimony itself. The deposits are generally found in or by the side of dykes or rather fissures traversing the sandstone, filled with a whitish quartzose rock, and usually having well-defined walls.[1]

The Tæ-læ-dwin, or so-called antimony mine, worked some time ago by Mr. O'Riley, then Deputy Commissioner of Maulmain, is situated on a hill called Lekka Toung, at the 23rd mile from Maulmain on the Amherst road. It is merely an open quarry, some 50 feet in length (north-west—south-east), roughly rectangular, with a breadth of 12 feet, and about the same in depth. The deposit is divided by well-defined walls from the ordinary yellow sandstone surrounding it.

The ore in these deposits dies out entirely, and no lode or even string is left to show in what direction more may be found. Sandstone surrounds it on all sides, and the only chance of any indication lies in the occurrence of an outcrop along or near the line of the dyke or fissure. From a single deposit a few tons only of ore is obtained. The richest ore is in the centre, and may contain as much as 70 per cent. of antimony (metal), and from this it graduates off into a blue slaty stone containing 2 or 3 per cent. only of the metal.

Practically the chances are small in favour of the idea that small unconnected deposits like this can ever be profitably worked. Should lodes be found however, the case would be different.

Through the energy and enterprise of a well-known advocate of Rangoon, mining operations on a small scale have lately been prosecuted to prove this range of hills, as to the existence or not of true lodes in them. A hill seemingly favourable for mining purposes was selected, and a level is being driven through at a short distance from its base. This work on completion will, in all probability, settle the question of lodes or no lodes for the Maulmain end of the range, the hill being a typical one as far as can be judged. A great expenditure of dynamite is found necessary in cutting through the siliceous slaty rock mentioned

[1] It is to be regretted that Mr. Criper cannot give a more precise description of these rocks. There seems even some doubt whether the 'sandstone' in which the stibnite occurs may not be a partially disintegrated metamorphic rock. The quantitative diagnosis of the deposit is however the important point of the paper.—H. B. M.

above. Iron pyrites is occasionally met with in this slate, and on the whole appearances are not entirely unfavourable for the occurrence of mineral in veins.

I may here remark that copper ("copper scoria") was said to be found at a place called Kyiek Myraw, on the Ahtaran side of this range, by Mr. O'Riley,—*vide* Selections from Records, Bengal Government, VI, 1852. On inspection I found three large mounds, each containing many thousand tons of rich iron slag. Enquiries on the spot from the old inhabitants and phungies (priests) failed to elicit any knowledge or even tradition of a furnace having been in operation there. No iron lode could be found and no excavations were known of in the neighbourhood. Probably a very rich form of laterite occurring there—almost an iron ore in fact—was used in the production of this slag. I have since learnt that more of such slag exists at a place called Wagardo, near Amherst.

Among the drawbacks to the carrying out of mining and prospecting operations in British Burma, the want of roads, badness of the conveyances, thickness of the jungle, and cost of labour, are the chief. An ordinary cooly's wages amount to Rs. 12 per month in Maulmain, and in the district 8 annas per day, except during the paddy season, when 12 annas per day is usually demanded. The coolies are chiefly Madrasis, with a few from Calcutta, the Burmese being too lazy and independent for hard work. Domestic servants are also Madrasis, a 'boy' requiring Rs. 16 and a cook Rs. 18 to Rs. 20 per month. In the district the usual means of conveyance on land is the Burmese cart drawn by two bullocks. As the body of the cart inclines from front to back at an angle of about 45,° a long journey in one does not afford the acme of comfort.

The best time for prospecting is from December to April, May and June being too hot, and from July to November every thing is under water, the rainfall being 170 to 220 inches in Maulmain, and nearly that amount in the other parts of Tenasserim.

Government dak-bungalows are few and far between, but along the high roads at frequent intervals zayats or rest-houses are found, built by pious Burmese, it being considered a good work to build a zayat and as helping towards the attainment of Nigbán.

Notes on the Kashmir Earthquake *of* 30th May 1885, *by* E. J. JONES, A.R.S.M., *Geological Survey of India.*

The chief shock.

On the 30th May, within a few minutes of 2-45 A.M., at which time a pendulum clock, set to local time, at the Residency in Srinagar, stopped, a severe shock of earthquake was felt in the Kashmir valley, where much loss of life and damage to property occurred. The shock was also felt to a less extent in all the surrounding country, and at Simla, Lahore, Peshawar, &c.

Subsequent shocks.

This shock, which seems from its effects to have been of a severe character, has been followed by slighter shocks up to the present time. On one day, soon after the chief shock, as many as thirty-three distinct shocks were counted at Baramula. The frequency of the shocks has, however, now considerably diminished, some days being quite free, and on

other days as many as four or five being felt in the day. As an example, on June 15th there was a shock about 4 A.M., which was more severe than those which have occurred recently; two hours after another shock was felt, but of a much less severe character.

Shock preceding the chief one.

The chief shock of May 30th seems to have been preceded on the evening of the 29th by a slight shock, which was noticed by several persons.

Damage done by the shock.

The loss of life and damage to property, though much less than was at first reported, has been very considerable. The number of persons killed by falling buildings according to the present official reports was something over 3,000, while the number of cattle, horses, &c., killed was very great.

Area over which the shock was severely felt.

The area over which the shock was sufficiently severe to do serious damage to buildings is also much less than was at first supposed; it extends from the neighbourhood of Srinagar on the south-east, round a little north of Sopur, and by Baramula down the Jhelum valley as far as the fort of Chikar near Garhi; the country south of Sopur has also suffered as far as Magam (or Margaon) on the road from Srinagar to Gulmarg. About 25 miles north-30°-west of Uri is a solitary case where a fort near Titwal on the Kishengunga river has been slightly damaged. Down the valley of the Jhelum between Uri and Chikar the damage has not been general, the forts being the only buildings that have suffered. The area over which the shock was severe enough to cause a large amount of damage may be roughly estimated as between 300—400 square miles, though the actual area including all the damaged buildings is something over this.

Style of buildings.

Most of the buildings consist of stones and wood in which mud takes the place of mortar, and they are covered by a heavy roof, frequently composed of dried mud supported by rafters, resting partly on the walls and partly on a few wooden pillars inside the building.

Difficulty of drawing conclusions from the effects on the buildings.

These buildings do not throw much light upon the direction in which the wave travelled, as they appear, when shaken by the shock, to have been unable to support the weight of the roof, which accordingly fell down inside the building and in most cases crushed any living thing of any size to death, while the walls having nothing to hold the mass of stones and (in many cases rotten) wood together fell to pieces; in some cases however parts of the walls fell down and the roof remained. Very little, if any, assistance can be obtained from these structures in obtaining data as to direction in which the wave travelled; the difficulty is also enhanced by the fact that the ruins were immediately disturbed and dug into in order to rescue the wounded and get out the bodies of the dead, and to obtain the wood for the purpose of erecting temporary huts.

Possible path of the wave.

There are, however, some circumstances that point to the conclusion that the wave path ran nearly north and south at Srinagar, as a hanging-lamp at the Residency was found after the shock to be swinging approximately north and south, though no exact observation of the direction was taken. The cracks in the walls of the Resi-

dency also tend towards this conclusion: those walls which run north and south exhibit cracks, while the long walls running east-west have not been cracked, though they have become separated from the north-south walls by cracks. At Baramula, of those buildings which are at all favourable for observation, the walls running east-west have fallen more generally than those running north-south, as for instance the dâk bungalow, a long building containing six sets of rooms, where the north wall facing the river and the roof covering the chief rooms, fell, while the back of the bungalow to the south suffered but little damage. In the fort at Baramula, which is partly built with mortar instead of mud, the tower at the north-west corner fell into the river, and the west wall running north and south has been cracked, and the top of both the east and west walls has fallen down.

The forts and huts which have been damaged along the valley of the Jhelum to the west of Baramula afford no trustworthy evidence.

Earth-fissures.

At Baramula and higher up the river a number of earth-fissures have been formed along the banks of the river, and occasionally at some distance from the river. The fissures I have seen were parallel to the course of the river, but owing to the water in the river standing at a very high level at the time I passed up, the surrounding country was flooded, and I was unable to see many of the fissures that are said to exist.

At Patan, which is some distance south of the Wular lake, there are some fissures running south-east—north-west and parallel to a line of low hills. I also noticed at this place one fissure running at right angles to and crossing all the rest. The size of these fissures varies from an inch to a yard in width. I saw no single ones of more than 100 yards in length, though they run into one another. The depth cannot well be seen, as the fissures are now blocked up.

Larger earth-fissures.

I am informed that there are some much larger fissures at a short distance from Baramula, some of them being 30 yards in width and a quarter of a mile or so in length. I hope to see them before my observations are concluded.

Sand craters.

In the neighbourhood of the fissures there are numerous patches of fine sand which have been forced up from some distance below the surface; they vary from 2 to 5 feet in diameter. The villagers state that at first this sand gave off a sulphureous smell. The sand resembles fine river sand, but differs slightly in character in the different localities where it is found.

Sounds accompanying the shocks.

The shocks were accompanied by a sound which, in the case of the chief one, was described to me as like a hundred cannon going off at once. The noise appears to have preceded the shock by a short interval of time and to have come from a northerly direction.

CAMP SRINAGAR,
The 18th July 1885.

Preliminary notice of the Bengal Earthquake of 14th July 1885, *by* H. B. MEDLICOTT, M.A., *Geological Survey of India.*

Some mention of this earthquake may be expected in the current number of the Records, but it can only be to announce that observations are being made by officers of the Geological Survey where the shock was most severely felt. Mr. C. S. Middlemiss is taking notes at Serajganj, Sherpur (in the Bogra district), Maimansing, and Dháka (Dacca); and Mr. P. N. Bose is visiting Nattore, whence some peculiar effects have been reported. The time of the occurrence was rigorously fixed for Calcutta by the stopping of the three regulator clocks at the Meteorological Observatory, from which the time-signals to the port are made, as checked by daily astronomical observations; the hour was 6h. 24m. 12s., on the forenoon of the 14th. The clocks stand due north-south, facing east. It is very doubtful that any comparable observation can be obtained elsewhere; but the time element is not the most important. As to the direction at Calcutta, the most reliable observation I have heard of was that by Mr. E. C. Cotes, of the recently filled cistern of a gas-holder on the premises of the Indian Museum; the water was seen to spill to a little east of north. This is, too, the direction suggested by the general report of damage done, which is very markedly concentrated in the upper deltaic area traversed by the Brahmaputra. In parts of this area slight shocks and tremours have continued since the main shock until now. No notice of the shock has been reported from Cachar or Upper Assam, which is the region most frequented by such visitations in this part of India. As to the angle of emergence, I know of no safe data; cracks in the walls of houses are numerous enough, but it is very difficult to make sure that they are not old ones that had been plastered over. The most distinct case of overthrow that has come to notice was that of a heavy plaster cast leaning against the north wall in a recess some 12 feet above the floor in the palæontological gallery of the museum, but it must have been in a dangerous state of unstable equilibrium; for several others similarly placed, and by no means so stable as they ought to be, did not fall. For the comfort of visitors I may add that these are now being made fast.

The area indicated is, so far as I know, a hitherto unsuspected position for a seismic focus, at least from recorded earthquake observations; but it is noteworthy that within that area, north of Dháka and west of Maimansing, lies the ground known as the Madhopur jungle, which was described by Mr. James Fergusson in his admirable paper on the delta of the Ganges[1] as due to an upheaval, "which there is every reason to suppose took place in very recent times." It is described as presenting a more or less scarped face of deltaic deposits along its western side, raised about 100 feet above the actual alluvial area, and sloping eastwards under the old bed of the Brahmaputra, and losing itself in the Sylhet jheels (swamps). This form is certainly very suggestive of an actual upheaval along the western edge, and this line, running past the end of the Garo hills on towards Sikkim (where the recent earthquake was very sensibly felt), would approximately suit for the axis of the seismic area as now indicated. But this view of the Madhopur jungle

[1] *Quar. Journ. Geol. Soc., London,* vol. xix, p. 329, 1863.

needs verification, for there are grounds for supposing that it may be only an insulated remnant of a former more extensive deltaic surface, other remains of which are found in the terraces of old alluvium at many places on the borders of the present deltaic alluvium.

There is another feature described by Mr. Fergusson (*l.c.* 333) that must be taken into consideration in the present discussion, namely, the change that occurred early in this century in the course of the Brahmaputra. When Major Rennell surveyed these rivers in 1785, the whole Brahmaputra, which is perhaps a greater silt carrier than the Ganges, flowed by Maimansing, east of the Madhopur jungle, and did much work in filling up the depressed area of the Sylhet jheels. It was then driven back from this ground by the comparatively insignificant eastern streams, as is so well explained by Mr. Fergusson, and fell over into the area west of the elevated tract, where it now flows some 60 miles to the west of its former course, in the very ground where the recent earthquake has done such mischief. It is not impossible that the accumulation of 70 years' deposits from the great river may have had some influence in producing the catastrophe.

There has been in the daily papers so much loose writing upon earthquakes on the occasion of the recent events in Kashmir and Bengal, that it may not be amiss to make a few general remarks on the subject. It is only partially true, and in respect of details, that the subject is 'shrouded in mystery.' It is not disputed that every smallest cause must have some effect: when a musquito alights on a mountain the state of equilibrium is somewhat different from before, when the monster's weight was distributed by air vibrations. It is well known that the volcano Stromboli is looked upon as a barometer by the sailors of the surrounding seas; still to speak independently of variation in atmospheric pressure as the cause of volcanic eruptions, and still more so as a cause of earthquakes, is to lose sight of all sense of proportion. In the same connection, there is no doubt that high-pressure steam plays a conspicuous part in volcanic phenomena and their attendant earthquakes; and that even in other earthquakes steam is ever ready to flash into any temporary fissure that may be formed; but to speak of steam scouring through subterranean caverns, bursting from one to another, and so causing earthquakes, is to indulge in geological romance *à la Jules Vernes*, for which there is little excuse when we have so much solid ground to judge from. No one who has ever been in a region of true mountains, such as the Himalaya, with his eyes open, should have any misgivings as to the cause of earthquakes, on seeing around great thicknesses of bedded rocks that must once have been flat, now twisted into knots and snapped asunder like twigs. Of course the hiatus in thought lies in the familiar assumption that the rocks were made so, or that all this performance came off in pre-Adamite times. The truth is that that sort of thing is going on now; the Himalayas themselves have not done growing. The crust of the earth is continually in a state of strain, owing probably in some degree at least to relative changes of the internal and external volumes due to secular refrigeration, and to other disturbances of equilibrium, such as the wholesale removal of matter from one part of the surface to another (of which the case suggested is an instance), amounting in time to enormous quantities. Thus there are re-adjustments of equilibrium always going on. They for the most part take place so slowly as to be imperceptible,

but sudden collapse must often occur, producing the shocks we know as earthquakes. It has been ascertained with much certainty that the greater earthquakes have their origin at considerable depths, as much as 30 miles, below the surface; though no doubt very destructive local shocks may arise from a much nearer focus.

The suggestion for warnings of approaching earthquakes is not promising, and it is only even plausible where seismic activity is more or less chronic. Of the greater disturbances that extend far from the focus there would probably be no symptom whatever, unless, perhaps, in the neighbourhood of the focus. Even at the seat of activity the attempt would probably be futile, for the many petty disturbances that pass off without serious sequel could hardly be distinguished from those that precede violent shocks, and the warnings would soon come to illustrate the "wolf, wolf" alarm of the nursery tale; so that such warnings might on the whole create a greater aggregate of anxiety and suffering than it was intended to relieve.

ADDITIONS TO THE MUSEUM.

FROM 1ST APRIL TO 30TH JUNE 1885.

Two specimens of alluvium—one from River Dharla near Mogul Haut Railway Station, Rungpore District, and the other from River Gangadhar, Assam.

PRESENTED BY MR. R. T. MALLET.

Lignite from Sivalik Sandstone, Bhútan, North of Barpeta, Assam.

FROM THE DEPUTY COMMISSIONER OF KAMRUP.

Various fossils (22 in number), from Perim Island and other places in Kathiawar.

PRESENTED BY AZAM VAJISHANKER GAURISHANKER, ASST. DEWAN OF BHAVNAGAR.

Cervantite, and antimony smelted from the same, from the Toungweine Range, near Maulmain.

PRESENTED BY MR. GEORGE DAWSON, MAULMAIN.

Specimens of phosphatic rock and phosphatic nodules, from Masuri.

PRESENTED BY REV. J. PARSONS, MASURI.

Section of a vertical pipe used for carrying the shaft water from one water ring to another in No. 3 Pit, Warora Colliery, the interior encrusted with a deposit of carbonate of lime, which was formed in fifteen months.

PRESENTED BY MR. C. J. BUNING, OFFG. DY. MANAGER, WARORA COLLIERY.

Specimens of egeran from the 'Rer' quarry, northern base of the Chattarbhaj Hills, Tonk.

PRESENTED BY LIEUT.-COL. W. J. W. MUIR, POLITICAL AGENT IN HAROWTEE AND TONK.

Three pieces of the meteorite that fell at Pirthalla, Burwala Tahsil, Hissar District, Punjab, on the 9th February 1884. The largest piece weighs 510·6 grammes; the second, 425·7 grammes; and the third, 224·2 grammes. Its specific gravity is 3·40.

FROM THE GOVERNMENT OF THE PUNJAB.

The greater portion of the meteorite that fell at Chandpúr, Mainpúri District, N.-W. P., on the 6th April 1885. It has since been cut into two; the larger piece weighs 625·5 grammes, and the smaller, 491 grammes, and its specific gravity is 3·25. It weighed 1201·3 grammes before cutting.

FROM THE COLLECTOR OF MAINPÚRI.

ADDITIONS TO THE LIBRARY.

From 1st April to 30th June 1885.

Titles of Books. *Donors.*

BALL, *V.*—On the identification of the animals and plants of India which were known to early Greek authors. 8° Pam., Dublin, 1885. THE AUTHOR.

BLANFORD, *W. T.*—The African Element in the Fauna of India: A criticism of Mr. Wallace's views as expressed in the 'Geographical Distribution of Animals'. 8° Pam. Calcutta, 1876. THE AUTHOR.

BRONN'S Klassen und Ordnungen des Thier Reichs. Band II, Porifera. Lief. 7; & Band VI, Abth. I. Fische. Pisces, Lief. 4; and Band VI, Abth. III, Reptilien, Lief. 43—45. 8° Leipzig, 1885.

Contributions to the History of Education. Historical Sketches of the Universities and Colleges of the United States. 8° Washington, 1883. HOME DEPARTMENT.

DAVIDSON, T., and KING. *W.*—On the Trimerellidæ, a Palæozoic Family of the Palliobranchs or Brachiopoda. 8° Pam. 1874. THE AUTHORS.

DOUGLAS, *Silas H.*, and PRESCOTT, *Albert B.*—Qualitative Chemical Analysis, 3rd Edition 8° New York, 1881.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1885. **[November.**

Sketch of the Progress of Geological work in the Chhattisgarh Division *of the* Central Provinces, *by* WILLIAM KING, B.A., D.Sc., *Superintendent, Geological Survey of India.* (With a map.)

The large area of country included under the above heading embraces, besides Chhattisgarh proper, a small tract on the eastern edge of Balaghat and Mundla on the one side, and a much wider extent of the Sirgujah and Gangpur territories of Chota Nagpur to the far east. At long intervals, since 1866-67, traverses across the whole region, or at several points on its borders and within it, were made by Messrs. Medlicott, W. T. Blanford, and Ball, their observations having been recorded in manuscript or in the publications of the Survey.[1]

The more connected examination of the area has been resumed within the last two years, and on the following already recognised provisional succession of formations:—

Deccan trap.	
Kamthi.	LOWER GONDWANA.
Barakar.	
Talchir.	
Limestone member.	LOWER VINDHYANS.
Sandstone „	
Chilpi beds.	? Do.
CRYSTALLINES.	

It was to be expected that closer work might possibly lead to a modification or even an enlargement of this list: as will be seen later on, this has been the case in so far as I have been led to look on certain rocks as belonging to a transition series rather than to the Lower Vindhyans,—a view at which I had arrived on

[1] Medlicott, M S. 1866-67. Blanford, M.S. 1869-70. Records, G. S. I., III., pp. 54 and 71. Ball, Records, G. S. I., IV., p. 101; VIII., p. 102; X., pp. 167 and 186. Manual of the Geology of India, Part I, pp. 75, 128, and 199.

independent observation of strata which had not escaped the vigilant scrutiny of Mr. Medlicott, who was also struck with their sub-metamorphic facies.

The sequence of the limestone and sandstone members of the Lower Vindhyans of the Chhattisgarh basin has already been discussed to some extent by Mr. Ball in these Records,[1] partly without due regard to the extent and completeness of the basin in itself and through a comparison of these with certain members in adjacent regions. The evidence gained in the present examination is, however, so clearly corroborative of Mr. Medlicott's first position that all questions regarding it may now be laid aside. At the same time, not only on this point, but on the view of the interpolation of a transition series and the possible absorption by it of some at least of the rocks included under the Chilpi beds, it would long ago have been of the greatest advantage had Mr. Medlicott's progress report been published. Its reproduction is now more desirable than ever, and, with the Director's permission, it is embodied in the present paper.

The most striking feature of the Chhattisgarh country is its great plain or basin which stretches far to the eastward and southward from the foot of the steep-crested and ridged slopes fringing the Mandla-Amarkantak plateau, or that part of it which is called the Maikal range. This range, and a great N.–S. spur stretching into Balaghat and Bhandara as the Saletekri hills, form a sort of rectangular north-west corner of the basin. Not far from the southern end of the Saletekris, the southward limitation of the basin is formed by the much lower Raipur, Bilaighar, and Sarangarh hills, the skirts of the long northern slopes of which, trend north-north-eastwards past Raipur and then away along the right bank of the Mahanadi ending in the Bara Pahar range, some 30 miles west of Sambalpur. The latter range drops down to the great river, on the opposite or left bank of which the rim or edge of the basin is continued in a series of high ridges striking north-westward past Raigarh, thus closing in the great plain at its eastern end. The hilly border is thence continued rather more west-north-westward across the Mand and Hasdu rivers, and so by detached and lesser ridges past Ratanpur (some 30 miles north of Bilaspur) to the foot of the slopes of the Maikal range below Amarkantak.

No more perfect geographical and geological basin could be instanced; for, except on the west and north-west sides, the rim-like edging of hills and ridges consists of gently or more strongly up-turned beds rising from under the flatter-lying strata of the plain with which they are formationally associated. We have thus come to distinguish what may be called the rocks of the plain, and those of the rim as synonymous with the 'limestone' and 'sandstone' members of the Chhattisgarh Vindhyans.

The Korba plains to the north-east of Bilaspur form a sort of supplementary or outside stretch of low country; but this cannot be looked on as a part of the proper basin, from which it is separated by the low ridges and larger hill masses of Ratanpur, Soti, and Dulha, while its main rivers, namely the Arpa, Hasdu, and Mand, cut across or through this part of the rim in their course to the Mahanadi. This tract is also geologically distinct, being made up of crystallines and Gondwana rocks.

[1] Vol. X, p. 167.

The Pendra upland to the north, which might also be considered a portion of the northern edge of the great basin, is remarkable as being a part of the divide between the great southern feeders of the Ganges and the northern drainage of the Mahanadi, as well as the connecting link between the Amarkantak end of the Satpura range and the lofty plateau highlands of Chota Nagpur.

CRYSTALLINE SERIES.

It is scarcely necessary, even if it were possible, considering the very cursory form of examination consequent on attention having been given to more important formations, to dwell at any length on the different gneisses and granitoid rocks constituting the floor of this field; though a general idea of their mode and style of occurrence may here be given.

On the north side of the basin, that is, by Lurmi, Pendra, Mahtin, Uprora, and Korba, good strong-bedded gneisses of the more massive quartzose, quartzo-felspathic, and hornblendic varieties, are common, particularly in the slopes or ghâts separating the Pendra country from the Bilaspur plains; though the upland itself, as far north as Pendra at any rate, is of unfoliated and very coarsely granitoid kinds. The ghât rocks are all more or less foliated, or laminated and bedded, in a general E.–W. strike, with a high dip to southwards, though this becomes less and less inclined towards the foot of the hills. A cross traverse from Pendra southwards by the Suknai and Arpa valleys shows the granitoid rocks to the edge of the upland, where they are succeeded by the foliated gneisses with which are associated frequent thick beds, or sheets of coarsely crystallized red felspathic granites, or more highly altered forms of gneisses. Strong quartzose gneisses, quartz-rocks, and some schists, still having the E.–W. strike, come in below the ghâts and occupy the low country (much covered up with alluvium) nearly as far as the Ratanpur group of hills. Other traverses in the same direction but further and further east, over the Lapha hills, or from Mahtin down to Korba, and in Uprora, show a similar succession of gneisses. The general E.–W. strike is not only seen in the rocks themselves, but it is, as it were, stamped on the face of the country in the wonderful system of long, narrow, and deeply-carved ridges and valleys to the south of Pendra and about Mahtin.

In the Korba valley, the crystallines are extensively covered up by Gondwana rocks; but a belt of granitoid gneisses, with subordinate hornblendic and quartzose schists, shows a few miles to the south and south-east of the town, and narrows off in the latter direction towards the Mand river. Gondwanas and Vindhyans then intervene as far as Raigarh, where a further thin belt of quartzo-felspathic granitoid rocks, with frequent ridges of quartz schists or quartz-rock (occasionally having more the character of fault rock) and bosses of hornblendic or syenitoid varieties, stretches in a south-east direction towards Sambalpur.

? TRANSITION SERIES.

In treating of these rocks, I labour under the disadvantage of having seen them in detached areas and then only on a traverse while marching across country to take up a far distant coal-field near Sambalpur; or, later again, when more especially following out the northern edge of the Chhattisgarh basin.

Further, they are at these places in contact or very close to, and in some of their characters not unlike bottom strata of the Lower Vindhyan outcrops.

On the march from Pendra south to Bilaspur, the gneissic rocks were traced into the rugged low country of Kenda; beyond which lies a wide stretch of superficial deposits in the Khaira valley, extending to the northern skirts of the low group of Ratanpur hills where are traces of quartz schists not so manifestly gneissic as those to the north in Kenda. The higher hill block west of Ratanpur, or to the north of the old city, is made up, on its south-western slopes at least, of a decidedly different set of rocks—namely, hard, massive, quartzose strata, generally of a green colour, associated with foliaceous and rather compact green mica schists or coarse clay slates weathering of pale-brown and reddish colours. There are also thick bands, apparently in the strike, of dark-green traps (greenstones) or trappoids. The low hillocks to the west and south-west of the old city consist of low-dipping quartzite sandstones and shales. There is some twisting and rolling about of the beds; but the general strike is N.W.-S.E., the dip being to the north-eastward. The low, but very steep, ridge on the western side of the Dulha tank is of much crushed and white quartz-stringed quartzite (nearly quartz schist) having a high dip to north-east.

Here, therefore, without taking into account the different style of the rocks, is a series having a strike in strong contrast with the prevalent E.-W. one of the proper crystallines; and not only is this the case, but even a stronger discordance exists between them and the Vindhyans, for these quartz schists of the Dulha ridge are crossed at their southern end by bottom sandstones of the latter series which are striking W. by S.-E. by N. and dipping 20°-30° southward. These sandstones are only some 60 or 70 feet in thickness, but they are well marked in the long low ridge forming here a part of the lip or rim of the great basin. The section is quite clear on the Bilaspur-Ratanpur high road.

The next exposure of similar rocks lies some 12 miles to the east-south-east, on the western slopes of the Soti Hill (2,646 feet) mass. On passing eastward from the Vindhyan limestones of the plain, about Pondi and Bamini, I found that the first ridges are of strongly-crushed quartzite and quartz schists, exactly like those of the Dulha tank ridge, having very much the same strike and vertical or with a high inclination to the eastward. These are then succeeded, after a narrow strip of covering alluvium, in the slopes by strong compact schists or coarse clay-slates, and hard massive dark-green quartzose rocks, with which are associated, to all appearance in the strike, greenstones and trappoid rocks. Like rocks are traceable over the Nilagar valley into the Dulha hill (2,447 feet) mass to the southward and away in an east-north-east direction by Baluda, almost as far as Panora on the road to Korba; the more prominent exposures being, however, quartz-rock or quartz-schist still having a generally N.-S. strike.[1]

LOWER VINDHYANS.

Mr. Medlicott's so long reserved progress report will form a fitting introduction to the consideration of these rocks.

[1] As will be seen in the next section, Mr. Medlicott had also visited this Dulha-Soti area, but my observations were made without having previously seen his report.

Vindhyans of the Mahanadi.

"When I first came upon these rocks in this section of the Hasdu, I took them to be Talchirs, and even tried for a couple of day to accept them as such. The colouring of Mr. Hislop's map gave a direct determination to this view; and at this particular spot it chances that the rocks lend themselves to that supposition:, there are thick beds of fine calcareous clays in abrupt contact with gneissose rocks. But the notice from the first of a considerable departure from the Talchir type rapidly widened into a total separation; although characteristic Talchir rocks were observed at a short distance to the north, I looked in vain for them here; and characters were soon observed, which have never been noted in Talchirs, but which are common in pre-Talchir groups.

Local resemblance to Talchirs.

Sandstones.

"The sandstones are strongly bedded, often coarse and rusty, often pure and fine, quartzite sandstones.

Clays.

"There are massive fine homogeneous clays, often affecting a flat nodular structure (resembling somewhat the splintery clays of the Talchirs). There are also finely laminated siliceous shales; these are often calcareous, and pass insensibly into finely laminated siliceous limestones, in the manner so common with some of the lower-Vindhyan bands of the Sone and of Bundelkhand. These shales seem also connected with fine flaky siliceous and *quasi*-felspathic beds, very hard and compact (porcellanic) on a fresh fracture, but betraying their flakiness by weathering. These beds, too, find their exact analogues in the lower-Vindhyans.

Porcellanic variety.

Limestone.

"Limestone is perhaps the commonest rock at the surface all over the plains of Chhattisgarh. It is seldom a pure homogeneous rock, being often flaky and earthy-siliceous, and often also the siliceous matter is distributed in strings or in irregular concentric concretions.

General order.

"It would seem to be only in the most general way that these several rocks observe any order of position. I think all these types may be observed as a bottom rock, resting upon the metamorphics. But there is a decided preponderance of the sandstone in this position. It would seem that the sandstones never attain a considerable thickness save at or near the base of the series; I would conjecture, too, that they are altogether absent towards the top. This variability in the deposits is also a point of similarity with the lower-Vindhyans, and with the rocks described this year by Blanford in the Godavari area.

Distribution.

"As the most frequent bottom rock, the sandstones are seldom seen in force, except near the boundary; but they are nowhere so much developed as in the south-east, resting on the gneiss of the Jonk area and of Sambalpur, and forming ridges running northwards from that area. If one wanted an appropriate name for the band, "the Chandarpur sandstone" might be adopted. I have nowhere seen them so well exposed, or in so great force, as in the ridges running south from the Mahanadi at Chandarpur.

"I can indicate no constant position for the limestone. It seems thoroughly associated with the shales overlying the Chandarpur sandstone.

"The position here distinctly assigned to the sandstone is the same as is conjectured by Blanford for the Pranhita sandstone, with reference to the Pem shales. In the Sone area a quartzite sandstone is the most general bottom rock of the lower-Vindhyans.

"In describing the boundaries of these rocks, the foregoing observations will be illustrated and amplified.

Southern boundary.

"The boundary of these Vindhyans with the crystalline rocks on the south is much more simple than on any other side. Here only is there a distinct and unequivocal case of simple unaltered super-position. Close to the right bank of the Mahanadi, east of Arang, the shaly, flaggy, dark siliceous limestone shows with a steady inclination of 3° to 4° to westwards; and on the rising ground to eastwards the strong-bedded sandstones pass up from beneath the limestones and shales to form a low range of hills. These hills present a gentle slope to the west, and are scarped along the eastern face, in which can be admirably seen the junction of the massive sandstone resting on coarse granitoid gneiss, and largely made up of its debris; this debris is not coarse and water-worn, but gravelly, and still undecomposed. The very gradual nature of the junction is well seen in the east–west gorges, the crystalline rocks appearing in the valley for a mile or more to westwards of the general north and south line of scarp, and with sloping scarps of sandstone on either side. From the steadiness of this feature, I was led to conjecture that the eastern extension of the sandstone would be limited with much regularity by the north and south line of scarp. I was therefore surprised to find the sandstones at one spot half a mile in front of that line, and at the general level of the crystalline are of the Jonk; but this is little more than 100 feet below the line of junction in the scarp; I imagine however that such outliers are exceptional on this side of the granitic area. In passing eastwards along the road, the scarped hill range I have just described is seen to the north curving round to the east towards Sarangarh; and I have no doubt the rock-features are quite similar to those on the east, the sandstones thus encircling the crystalline rocks on west and north.

"The Raipur and Sambalpur road runs nearly east and west, and for 50 miles there is no rock but crystallines; the sandstone hills appearing at a greater or less distance on the north. In Phuljhar there is a break; a bay (now a region of hills) of Vindhyan rocks stretches southwards from the main area of the Mahanadi, separating the crystallines of the Jonk from those of Sambalpur; the two being probably continuous on the south, in the Borasambar State. For a long distance to the west along the road the high scarped ridge of Siswal, in Phuljhar, betrays the presence of more regular stratified rocks. On the road, a few score yards to east of the Katli river, on meridian 83°, one comes, without any separating surface feature, upon fine crushed and slaty silt beds, with some associated beds of brown coarsish sandstone. Although much compressed, the stratification is not greatly disturbed, as can be seen by the lie of the sandstone, and by the position of the imperfect nodular structure of the clays which seems always to preserve the flatness in the plane of bedding. I at once recognised these rocks as identical with what I had seen about the north boundary and elsewhere in the Vindhyan area; and hopes were raised, that in the high

scarped hills close by on the east I should find higher beds of the series than any I had yet seen. On approaching Bindala hill (some 16 miles north of the road) I was surprised to come again upon crystalline rocks on the low ground and reaching up to the foot of the scarp. Further exploration in the same north-easterly direction confirmed this observation: crystallines weather out here, there, or anywhere, from under the sandstone, with small regard to levels. Thus the general character of the junction here is the same as to west of the Jonk; the bottom portion of the sandstone in the Phuljhar hills is disposed to be shaly rather than coarse and massive like that of the boundary in Raipur; and the fine argillaceous beds, the first rock noticed in these eastern sections, was not observed in the single section I examined west of the Jonk (from the greater regularity of the boundary there, I dare say they are nowhere exposed); but, as already remarked, these argillaceous rocks are exactly like beds seen elsewhere, and I believe them here, as elsewhere, to underlie and partly to represent the sandstone which caps the gneiss of the higher levels. In these sections we thus find locally well exhibited what I have stated to be the relation of the sandstone generally—that it cannot be looked upon as a bottom group of the series, although very often seen as bottom rock. There is no presumption either that it is generally represented along any horizon. I can give no certain criterion of the beds which overlie the sandstones as compared with those which underlie them; the latter appear to be less shaly and more massive and of a darker colour, and perhaps, free from limestone, although apparent exceptions to this will be noticed.

"From Phuljhar I marched northwards along the sandstone range to Chandarpur. The sandstone must be several hundred feet thick, and most of it is a fine, white, pure, quartzite-sandstone like much of the upper-Vindhyan rock. The range is on a distinct anticlinal; the pale shaly, flaggy, calcareous upper parts showing on both sides close to the base and inclined from it. The Kenkaradi river occupies a basin of these upper beds to east of the Chandarpur range; the hills to the south-east being, I have no doubt, formed of the sandstone sloping up in that direction and forming a scarp over the crystalline area of Sambalpur.

"Proceeding eastwards along the south boundary, there may be noticed a gradual change from the perfectly undisturbed condition of the normal junction in Raipur, as already described, to the greatly disturbed and very complicated junction that runs in a north-westerly–south-easterly direction through Sambalpur and Raipur and forming the eastern boundary of the Vindhyan area of the Mahanadi. The intricate and rugged hill group of the Bara Pahar is formed at the confluence of those two boundaries. Before attempting to sketch the features of the eastern junction, I will notice the less complicated one on the north:

North boundary.

"In going northwards from Bilaspur to Ratanpur, the shales, limestones, and subordinate flaggy sandstones, which spread horizontally beneath the plains of Chhattisgarh, are concealed by soil and alluvium to within 2 miles south of Ratanpur, where a low east–west range of hills rises abruptly from the alluvial flat. The ridge is formed by a band of strong-bedded standstones, mostly coarsish and with an insufficient rusty ochreous matrix, but some of it fine and pure. The band is not thick; may be 50 feet and under. It seems slightly to alternate with and to overlie streaked red and greenish slaty shales. Very locally one may observe apparent total unconformability between

the sandstones and the shales below them, but I believe these cases to be entirely due to crushing between yielding and unyielding materials; for in the best sections, as well as in the general *allure*, there is full evidence of conformable association. The nature of the disturbing action along this zone is best seen by the behaviour of the sandstone; the elevation from the north does not seem to have been very marked or very direct; for several miles in width the sandstone may be seen forming little ridges having any direction and slope, and all at about the same level. In the little ridge over Ratanpur this strike is north-north-east and the dip 30° to east-south-east; a mere capping of sandstone resting conformably on the shales.[1]

"On the Ratanpur section the junction with the crystallines is concealed beneath a longitudinal valley. The zone of special disturbance may be about 5 miles wide.

"I crossed this boundary again at some 30 miles to west of Ratanpur, where the rocks are better seen, and one actual junction exposed. At Lurmi the same band of sandstone forms very low (40 feet) ridges, rolling about at small inclinations, and with little regard to direction, the same type of disturbance as at Ratanpur; and it soon settles down under the pale shales and limestones of the plains to the south. In the Muniari, just above Lurmi the rocks under the sandstones are admirably exposed. They are massive beds of fine (? siliceous) clays, some exceedingly fine, others more gritty; mostly of a red colour, often streaked with green, and some greyish-brown. A fine lamination is often traceable in all; and the bedding is easily discerned. The dip is variable, not exceeding 10° to 12°—a southerly direction prevailing; but the effects of great crushing are manifest in the irregularly intersecting systems of planes of jointing or pseudo-cleavage that traverse the whole mass. In these also an east-westerly strike is the most marked; the effect of which is such that in mere ground-sections on paths one would note the rocks to be slates, with an east-west cleavage. In the finer beds the disintegration of the rock is further complicated by an original, flat, concretionary structure, which produces concentric exfoliation.

"At 3 to 4 miles north of Lurmi there is a very steady range of hills, running about 5° north of east, south of west, the south face of the crystalline area to the north. This straight ridge is here several miles wide, and tolerably flat-topped. The gneiss lasts to the edge of the south face; but the spurs, from the very top, are of streaked reddish and greenish slaty rocks; very locally even there is an appearance of incipient foliation. The water from the higher level trickles down over a steep surface of gneiss into gullies through the slates. The junction is amply exposed; there is no clean-cut plane of separation; not a sign of intervening vein rock; no trace of slipping between the two; within a few feet or inches the change is complete, the rocks being just as it were soldered together.

"By aid of the lamination, and of an occasional flaggy layer, the bedding can be observed; at the spot I examined there was, for a few feet wide, a low

[1] It is in these shales that copper ore was reported to have been found and formerly worked; but I could find no definite foundation for the report, nor any confirmation of it in the rocks. The piece of 'ore' sent to me by the Deputy Commissioner (Mr. Chisholm) was merely a bit of red (copper coloured) shale.

inclination towards the gneiss, and then a low inclination from it; the whole state being exactly like what is seen in the river at Lurmi, only slightly intensified.

"The observations I have recorded seem altogether to indicate a normal relation between these series of rocks—an aboriginal contact. This view is strongly corroborated by the appearance, about half-way between Lurmi and the hills, of a band of gneiss on the low ground. Its presence is not marked by any surface feature or peculiar contact-rock; it seems simply to have weathered out from beneath its covering of shales. The only thing to suggest a faulted boundary here would be its straightness: the run of the junction north of Lurmi would just about cut its position north of Ratanpur, 30 miles to eastwards. But a geologist in India ought to be the last to ignore the effects of straight scarped boundaries among the original conditions of rock formation.

"For some distance, at least, the same boundary runs steadily to westwards, but I should think that it curves southwards before reaching the trap scarp, for there are some symptoms of the lower boundary of the Vindhyan rocks being not far off from the western limits of the present area, although now concealed beneath the trap of the Mandla plateau.

Western boundary.

"One of the most striking general features of this area of Vindhyan rocks is the almost undisturbed condition of the strata all over the central area up to within a comparatively narrow belt along the boundary. Except on the partial south boundary first noticed, such is markedly the case. It is a remarkable instance of geographical extension prescribed by structural features in very ancient deposits; and it is doubly interesting to find symptoms of those structural features themselves being connected with original conditions of deposition. It will readily be understood how the arrangement I have just indicated should introduce a difficulty to the correct appreciation of the Vindhyan series itself: the topmost strata are almost confined to the low grounds, where they show the minimum of disturbance; while the bottom bands rise along the boundary and are often much modified by contortion and compression. One has to seek far and wide for proof of the two being really continuous. The contrast I have here described is nowhere more marked than on the section of the Hasdu, where (unfortunately) I first came upon these Vindhyans; and the degree of contrast will be illustrated when I say that for two days I noted the upper bands as Talchir (although of abnormal character), while the lower beds passed as a new form of hypo-metamorphics.

"It was along the western boundary that I got the best instance of the upper group being subjected to the full measure of disturbance. The scraggy east—west ridge stretching past Pandaria on the north is principally formed by the pink and blue cherty limestones and the shales so intimately associated with them, the same as are found spread out at the surface all over the low plains of Chhattisgarh; in this ridge all are confusedly crushed up on an E.-W. strike. In the hills to south-west of Pandaria the N.E.-S.W., and N.N.E.-S.S.W. strikes that obtain along the western boundary come in.

"The western boundary, as far as I saw it, bears a general analogy to that on the north; from Ratanpur westwards, a belt, some 5 miles wide, of hills composed in the main of slaty shales separates the plains from the scarp of the Mandla

plateau. A gradation of disturbance is observable from the base of the hills, wherever rock is exposed on the plains, the inclination being from the hills. In the outer ridges a band of sandstone is traceable; but towards the north it is very subordinate. The slaty shales forming the mass of the hills may well represent the similar rocks north of Lurmi. In the Chilpi ghât section, on the Bilaspur-Jabalpur road, they last up to the base of the scarp, where they are overlaid by the basalt, at a level corresponding to that of the general height of the fringing hills. There must be here a much greater thickness of shales than along the northern boundary; but here, too, the thickness need be much less than would be at first sight conjectured; for, although the strike is more steady than in the zone of disturbance along the northern boundary, reverse dips are observed, and also frequent exceptions to the N.N.E., S.S.W. strike, showing repetition of the same beds. There are also mineralogical characters corresponding with the stratigraphical differences I have noted. Well in towards the base of the main ascent trappoid rocks appear; but I failed to make out anything definite regarding them, or to separate them and the rocks with them from the general mass. I am disposed to think they may be local metamorphic forms of the Vindhyan shales in the line of maximum compression.

"I may here notice a peculiar rock only observed in this and in one other locality. For some little distance below the junction of the basalt on Chilpi ghât, I noticed the surface strewed with large (10″ to 12″) well-rounded boulders of quartz and of crystalline rocks. At first sight I took them to be debris from the infra-trappean conglomerate; but this notion was soon dispelled by the fact that many of the boulders were more or less shivered, and re-cemented, after slight distortion, by silica—an evidence of violence never observed in Lameta beds. I soon found the boulders in place in the underlying series imbedded in a crumbling earthy slaty matrix, in which I could detect a high westerly underlie. This is here the contact rock, overlaid by a few feet of white Lameta limestone, which is succeeded by a dark greenish-grey earthy crystalloid sub-amygdaloidal trap. This conglomerate may, perhaps, be taken as confirmatory of the conjecture already hazarded, that the crystalline rocks are not far off to westwards, although the boulders are so thoroughly rounded that they may have traveled any distance; the whole deposit has a diluvial character that suggests the proximity of fringing declivities. The other occurrence of this conglomerate is more obscure: it is on the east of the Vindhyan area. The sandstone ridge of Chandarpur has been described as running north and south; an axis of contortion (presumably in connection with subjacent features) between two basins of the upper strata. The range terminates in the Mahanadi at Chandarpur; but in the line of its continuation unusual disturbance is traceable, affecting even the upper beds of the series. At about 5 miles north of Chandarpur a small north-south chain of low hills occurs; to all appearance they are composed of a mass of well-rounded boulders just like those of the Chilpi ghât section. I could nowhere get at the matrix in which they are buried; it must be some soft material like that of the Chilpi ghât conglomerate.

"South of Chilpi ghât, the characters of the western boundary are similar to what has been described. Below Sahuspur, the sandstone becomes more prominent in the outer ridges, and the slaty and hypo-metamorphic rocks below it are also more

developed; above Madanpur, they rise to the top of the main scarp, without any capping of Lameta beds or of trappeans. These rocks, underlying the sandstone, may probably be studied to advantage in the ground to south-west of Mohanpur.

Eastern boundaries.

"It was noticed along the southern boundary that there is a gradual increase of irregularity and of disturbance from west to east, coming to a climax in the Bara Pahar, north-west of Sambalpur, at the confluence of the two boundaries. There is a very similar change, but much more complicated on the north, where the Kamra hills offer a very close analogy to the Bara Pahar. The very regular and comparatively simple junction described to west of Ratanpur is altogether changed to east of that place; the crystalline rocks, which seem throughout to underlie the belt of disturbance at no great depth, rise to the surface; and the line of contact from close to Ratanpur to beyond Dulha hill, 20 miles to south-east, follows a very irregular course, which I had not time to follow out in detail. In this area, south-east of Ratanpur, there are decidedly metamorphic rocks, altogether different from the thorough gneissic rocks of the region to the north; there are also rocks which so exactly affect the characters of the bottom Vindhyans, that I must, provisionally at least, identify them as such, while at the same time I failed to detect any decided separation of these quasi-Vindhyans from those quasi-metamorphics. I can only hope to describe the facts and state the difficulties intelligibly, without offering a very decided opinion thereon. Let it be remembered that I made no stay to work out the case: I am only recording single observations.

Hasdu section.

"In the section of the Hasdu, the case is stated most clearly. Immediately below Satiguri there is a contact well exposed. The fine-grained gneissose quartzites, which form the rapids of Chicholi, are still vertical with a northerly strike. A strong bed of coarse rusty pebbly sandstone seems to rest upon a weathered surface of the metamorphic quartzites; the section is very low; and considering, as I did at the time, these overlying beds to be Talchirs I did not examine the contact so closely as I should otherwise have done, but I believe the relation to be as I have stated it. The sandstone slopes southwards, and is overlaid by fine pale shales, and these again by a strong band of tough grey (non-felspathic) sandstones with pebbly surfaces. Thick dark-grey shales succeed, and are overlaid by paler calcareous beds, locally a banded laminated limestone. The pale red varieties cover these and occupy the surface south of Nowagaon. These beds are the regular upper members of the series, and the sandstone represents that already so often mentioned. Its thickness here may be 30 to 40 feet in the two bands. It forms the little ridge running for miles to west-south-west from the river. It may be affirmed that no supposition could bring into original conformable relationship the rocks here in contact, they remain now as at the first.

"To one coming from the north the Kamra hills at once appear as something new: such steep clean cliffs, with well-marked lines of stratification, are never seen among the gneiss rocks; and, on the other hand, the rusty colour of the cliffs, and the sharp angularity of the outline at once distinguish them from the corresponding features in the hills of the secondary rocks. They are formed of a considerable thickness, not less than 200 to 300 feet, of quartzite sandstone resting

upon a very variable thickness of reddish gritty shales. The condition of disturbance is exactly what has been so often described in the bottom Vindhyans of this area; the ridges run in every direction, and with any slope just as if the stratification had been broken up by horizontal converging pressures. I have one observation to complete the analogy of these rocks with the bottom Vindhyans of other parts of the area. In the gap to west of the village of Labed a thorough granitoid gneiss shows well up to the base of these covering rocks, so as to leave scarcely a possibility of any relation but one of normal superposition. The relation of these rocks to other metamorphics of this neighbourhood is by no means so simple. The Kamra hills reach up to the left bank of the Hasdu. In the little stream flowing northwards from the Rang ridge, there is an excellent section of the whole group, the sandstones showing in the cliffs on both sides and the red shales in the gorge; for a long way they observe a steady dip of 5° to 10° to north, and just before they disappear in that direction there is an appearance of contortion. In the lower ground further north one only finds rotten unrecognisable gneissose rocks. In the Hasdu the rocks come in all of a sudden at Jogipali. It was here I received the impression that the little-disturbed, little-altered rocks of the hills become rapidly contorted, and at the same time metamorphosed into the fine-grained, sharply bedded gneissose quartzites (a most decidedly metamorphic rock), which come in immediately below and occur more or less continuously with a varying strike down to the junction at Satiguri,' as already described. If such be the case, these Kamra rocks cannot by any possibility be grouped with the strata to the south of Satiguri. I am, however, so strongly impressed with the view that the Kamra beds are the bottom Vindhyans, that I fully expect a close examination will prove them quite distinct from the subgneissose rocks of the Husdu.

"In the region of the Nilagar the same puzzle is even more strongly marked: the limestones greatly predominate in the upper beds on the low ground, and so occur close to schistose rocks at the same level; I conjecture that they may even be found to lap over in contact with them. They are thus found not far from the base of Dulha hill, on top of which the Kamra quartzite sandstones are easily recognised, resting on schistose and pebbly gneissose massively-bedded rocks. The Soti hill group is altogether formed (at least on the south side) by this new hypo-metamorphic series, a massive trappoid variety being prominent. A northerly and southerly strike is as markedly prevalent in these metamorphic rocks, as the E.-W. strike is in the granitic metamorphics to the north.

North-east boundary.

"Between the Kamra hills and the Bara Pahar, the boundary of the Vindhyans is marked through the Raigarh State by a single ridge, on a line with the outer (eastern) flanks of those hills. This ridge is formed of strong beds of quartzite much crushed and altered, gneissose rocks showing everywhere along its outer base. To the north these are of a coarse, highly felspathic, and granitoid type; but towards the Mahanadi they have a very mongrel character, which greatly obscures the distinctness of this junction. Close sections are obtainable at the passage through the ridge in the stream north of Padampur; the quartzite shows within a few yards of the bank at the point of the ridge having apparently a high dip towards the

crystallines; in the river the quartzite seems to be cut out, and there only appear reddish, flaggy, slaty shales, much crushed and rolled, but also on the whole having an inclination towards the crystallines, which are in place some 30 yards up stream. They are variable gneissose and trappoid schists. Here and in other similar positions (as in the stream under Laka to the north-west), I noticed a highly siliceous angular rock to be prominent among the metamorphics, suggesting the possibility of its being a transformed condition of the quartzite; but the general evidence is so strongly against such an interpretation that I must explain this special circumstance as either a coincidence (may be attributable to pre-Vindhyan denudation), or else as an effect of percolation-metamorphism along a plane of junction. The features here reminded me very forcibly of those at the boundary of the lower-Vindhyans, where the ridge of bottom quartzite is cut by the Sone at Bomarsan.

"The junction is tolerably well exposed in the Mahanadi at and below Padampur, and the section is altogether obscure and exceptional. The curve in the river above the town corresponds with a regular curve in the ridge of strong quartzite sandstone on the right bank. From a steady dip of 20° to westwards this sandstone bends round to a similar steady dip to north and north-north-east, apparently passing under the limestones and shales which are freely exposed in the bed of the river, with the same inclination as the sandstones towards the left bank. In this bank under Padampur, and lower down stream, there are those quasi-remnants of a quartzite (as described in last paragraph) adhering to and trans-fused into the dirty crushed gneiss. Just below the village the channel is about 30 yards wide between these rocks and an island of strong pink limestone with shales. The boundary runs very obliquely across the river; and at its last appearance on the left bank there is a remnant of the limestone and shale, quite unaltered, in actual contact with the mass of pseudo-quartzite and the crushed gneiss rocks. The section exposed is very small, but I could detect no special signs of faulting, such as slickensides or vein-rock, although the features described (with upper rocks at the contact) would *primâ facie* suggest such a phenomenon, and I am not fully prepared to deny the possibility of it. However it may be, it is evident that the passage of the Mahanadi at this spot is connected with the peculiar arrangement of the rocks.

"There is in the Vindhyans of this neighbourhood another exceptional appearance awaiting solution. The ridge of sandstone that has been noticed as bending round with the curve of the river on its right bank, encloses on the west and north the little valley of Dongri, forming a scarp over it. On the floor of the valley strong-bedded limestone with shales, exactly like the usual rocks of the upper part of the series, is exposed, showing little or no disturbance, and thus appearing to pass under the sandstone of the scarp. On the east side of the valley a strong band of exactly similar sandstone slopes up from beneath these limestones and shales. I had not time to examine whether there was a repetition by faulting, or whether the Lahansara sandstone is a local band in the upper strata of the Vindhyans. The latter supposition seemed the most likely. It is from the Dongri valley that most of the 'Padampur' limestone is obtained.

"There is evidence in this region that the boundary I have described was not always the limit of extension of the Vindhyans. At about 3 to 5 miles from

that boundary on the north-east there is a broken chain of ridges running parallel to it, and formed I believe of the bottom quartzite. It would seem to be the continuation of the outer ridge of the double range to north-west of Raigarh. From the debris noticed in the valley of Tarukpur, I conjectured that the crystallines were exposed somewhere within it. Thus here, as on the south-east side, we seem to have the actual base of the series exposed all along, the leveling by denudation having here been much aided by the compression and disturbance of the deposits."

The route taken by Mr. Medlicott in this traverse certainly placed him in very close *rapport* with the whole geology of the basin; for he entered it first on the north side from Korba by the Hasdu river, and thence proceeded westward, southward, and eastward all round the edges to the crossing of the Mahanadi at Chandarpur. Then, northwards from this up the valley of the Mand, thus crossing the eastern end of the basin; and so down again along the north-eastern edge by Raigarh to the extreme eastern boundary at Padampur. Little room was therefore left for other than the corroborative evidence which might be accumulated during the progress of connected work. This closer work so far has embraced the greater part of the middle and north-eastern tracts, and the whole of the western portion down to south of Raipur.

All the indications on the north-eastern tracts bear out the original recognition that the Chhattisgarh Vindhyans of the plain and the edging ridges consist, broadly speaking, of a sandstone and a limestone member, the former being the lower of the two: and there is ground for belief that such may be the conditions for the western side. However, I leave the conditions of the geological structure of this side an open question, because the evidence obtained by Mr. Bose in that part of the field, though as yet incomplete, shows that the relations between the rocks of the plain and those of the adjacent hill slopes of the Saletekri range are not so easily interpreted as Mr. Medlicott's reconnaissance would seem to imply.

It is true that occasional narrow seams of slaty shales and coarse schists do come in under, and in association with, the bottom sandstones along the northern boundary, but these are so insignificant as not to affect the general sequence. What they do seem to show, however, is that the bottom member—an essentially sandstone formation on the north-eastern, eastern, and southern sides—either gradually changes from a poorer and poorer sandy series to a stronger and stronger shale or slaty one with subordinate sandstones on the north-western edges, or that it continues on in this impoverished condition, sometimes being overlapped by the limestones, over a different and older series.

Later observations on the north-east boundary.—There is no necessity at present for going into detail regarding the style of the boundary from Padampur north-westwards past Raigarh. For the most part, it is a generally faulted one, the bottom quartzites, which must be here of great thickness, cropping up at high angles from under the much less disturbed limestones and shales of the plains, and having—what look to be—their lower strata, at the eastern bases of the great ridges, in close and abrupt juxtaposition with the crystallines of the low grounds beyond. I am myself inclined to suspect that there has been re-duplication, if not inver-

sion, with a crushing-up and fracture of long ellipsoidal dome-like undulations. Be this as it may, the whole aspect of the boundary is very analogous to that of much of the eastern frontier of the great area of Kadapah and Karnul rocks in the Kistna and Nellore districts of the Madras Presidency.

Some 5 or 6 miles to the south of the passage of the Mand river across the sandstone rim of the basin, a most instructive example of a crushed-up and partially faulted dome of the bottom sandstones is exhibited in the Gida hill mass which has been cut into and scoured out by denudation until the internal core of crystallines is fully exposed to view. A good deal of faulting and crushing is disclosed here and there along the contact edges in the interior; but the easy lie of south-easterly dipping strata is quite plain under Bamandai hill and on the path leading out to Basnajhar. A very thin streak of brown rusty, reddish and greenish schists, and sandy—rather sharp gravelly—shales occurs at the very contact, just between the gneiss and the thicker beds of quartzite sandstone on this path. Round the southern skirts of the hill the sandstones run easily under the red-purple calcareous shales and grey-blue limestones of the plain.

Some idea of the thickness of the sandstone series is also obtainable at this point,—a feature which had hitherto only been guessed at in the Raigarh ridges, where undoubted bottom beds are not recognisable in contact with the gneiss. Here, however, the base is known, and a fair estimate can be formed from the lofty scarped faces and under-cliff of Bamandai hill (1,439 feet), and from a scramble across the Gida ridge near its summit (1,480 feet) where the beds are vertical, though down either slope the dip is generally to westward, the angle decreasing towards the foot of the western side. In this way the conclusion is forced on one that there must be at least 1,000 feet of more or less altered (quartzite) sandstones, rarely coarse and gravelly, oftenest thick-bedded and fine-grained, and without any conglomerates as far as I could see. Their likeness to those of the Raigarh ridges is strong in every way; indeed there cannot be a doubt of the two belonging to one and the same group.

To the northward of this dome, after an interval of shales (and strong blue limestones at Banipathar) in abrupt contact with a north-south exposure of crystallines, the sandstone hills of the rim hade up in long gentle slopes, the beds lying at 5°, 10°, 20°, southward, with surfaces wonderfully worn in sinuous curves and zig-zags of contour. This easy lie only lasts for about half the width of the hills; when undulation, at first slight and then quick, has allowed of more rugged denudation, giving the broad and humpy masses overlooking the low-lying wide expanse of the Mand valley coal-field, the rocks of which lap up against the sandstone hills, or are only denuded for short distances, giving exposures of crystallines in abrupt juxtaposition with the Vindhyans.

Away to the north-west, the sandstone hills attain higher elevations as in the Gar hill (1,948 feet), the floor crystallines being exposed in the valleys and on slopes below lofty scarps; while outlying isolated strips of Vindhyans occur in such abrupt relation to the surrounding gneisses of the plains beyond that their position can only be accounted for by their having been let in by faulting.

No better display of faulted or squeezed folds, remnants of arches, and natural boundaries below scarps, can be pointed out than that of the Kamra range still

further westward. The Kamra mass (2,878 feet) itself has its lower slopes of crystallines crowned by a somewhat crushed synclinal of thick-bedded sandstones, with a good band of overlying red shales in the hollow above, giving scarped edges on the northern face of some hundred feet high; and, in the deep valley between this mass and the proper rim, one may recognize the remains of the great core of crystallines and its covering arch of sandstones.

A magnificent display of dip slopes occurs in this neighbourhood, on the southern flanks of the Pidadei (2,836 feet) ridge. Broad bed surfaces of dark black-brown weathering sandstones slope up from the narrow valley, inside the low foot-hills edging the plains, at an angle of 30° or so, with hardly a break, to the very crest of the ridge, the sharp and jagged bed edges of which stand out clear against the sky. There is scarcely a foot-hold on these slopes for any but the local jungle people; and it is merely where jointing and weathering have facilitated the scouring out and breaking up of ledges and the gathering of angular debris in stream-like heaps tailing up the slopes, that scrub and low jungle have been able to grow and vary the dark expanses of bare rock sheets.

Westward of the village of Labed, at the foot of the Kamra hill, an open country of crystallines extends to the Hasdu river, its southern edge being fringed by the low slopes leading up to the now simple and much less lofty edging rim of sandstones in the Sidapat (1,524 feet) and Rang, or Maruarani (1,713 feet) hills. In this direction, too, the thickness of the sandstones diminishes very rapidly; so much so, that beyond the Hasdu, in the Sandadi and Jogia (1,113 feet) undulations there can scarcely be more than 150 to 200 feet. The natural pose of the sandstones on the gneiss is fairly well displayed; but it is here that their lowest strata become decidedly thinner and more flaggy, while associated with them are sharp gravelly sands, sandy shales, and coarse schistose and clay-slate layers; in fact a stronger show of the contact beds seen in the Gida hill.

An interesting feature about this Rang or Maruarani region is, that though the hill appears at a distance to be capped with sandstones, and to have a certain slight scarp, after the fashion of the edging hills over the country already described, it is really only covered or scarped with those more flaggy, shaly, and coarse sandy gravelly strata just described. The bulk of the massive sandstones lies well in from the scarp or outer edge, being underlaid by about 30 feet of clayey and sandy flags, shales, and flagstones, which crop up and form a good deal of the upper part of Rang and Maruarani, as well as the edge of the low scarp topping the slopes on the left bank of the Hasdu river and overlooking the villages of Jika and Mohara. This western scarp is very instructive; for it shows the bottom beds of the sandstone series all along its crest as they rise gradually northwards to the Rang spur, over which they roll easily and bend down almost to the plains. In descending from the hills to Jika, the scarp or edge of the descent is very thin, about 10 feet or often less, consisting of a bed or beds of coarse black or reddish-brown ferruginous grits, made up of grains of white and glassy quartz in a ferruginous matrix, gravelly or pebbly towards the base, or sometimes having larger scattered pebbles of the same kind of quartz. This hard bed lies directly on east to west striking micaceous schists, or coarsish crystalline granular micaceous rocks easily

weathered; or there is at intervals a varying thickness of greenish and dirty-grey earthy micaceous clay-slates coming in between it and the sub-metamorphic rocks.

It is necessary to state here that this undoubted bottom bed of the Vindhyans is lying unconformably on the micaceous schists and other rocks constituting the slopes leading down to the Jika river flat. At the same time, it struck me that these subjacent schists could hardly be considered as belonging to the regular crystalline or gneissic series, though they look more metamorphic than transitional. There is an E.–W. strike in the slopes and away down in the plain, the general strike in fact of the true gneisses to the north; but this is apparently only local, as they seem to trend round on the opposite bank of the river and assume the N.–S. strike exhibited by the peculiar quartzite or quartz-schist bands lower down about Satiguri, and away to the westward towards the Dulha and Soti country already treated of as showing rocks having a transtional aspect.

The style of the bottom sandstones westward from this point on the Hasdu is given in Mr. Medlicott's paper (*ante*); but it may be mentioned here that I have representatives of them at the extreme north-west corner near Borla where quartzite sandstones and pebble beds occur underlying the limestones.

The rocks of the great plain are essentially limestones and shales which roll about in long, easy undulations, or are comparatively flat for many square miles at a time. It is only here and there, however, that exposures are frequent or of any extent, the most of the plain being covered with alluvial clays or soils of various kinds, beneath which the limestones or the shales may be found at a moderate depth. The shales are nearly always of a red-purple color, with pinkish or greyish shades: very rarely are they of green or dirty grey, or dark colors, though this is their style in the immediate neighbourhood of Raigarh. The limestones are generally grey or fawn-colored, sometimes pinkish or pale-reddish purple, often almost black, or dark blue-grey; thick-bedded compact splintery, or flaggy coarse and earthy or clayey where they shade up or down into shales; they are very often siliceous throughout, or seamed with fine films of siliceous matter, and chert bands. The more clayey and shaly laminated bands are often remarkably concretionary with polygonal, sub-spheroidal, and flattened oyster-like masses packed together over the bed surfaces, or along inter-laminar bands of more compact clayey constitution. Both shales and limestones are more or less cleaved round the edges of the field, more particularly so perhaps at the north-west corner. It is difficult over such a flat and ill-exposed country to say whether there may not be more than two steady bands of these rocks: it appeared to me that, broadly speaking, there is a tendency in the whole member to be generally shaly at the bottom, the limestones coming over in varied force; though there is also a tendency in the shale band to have subordinate seams of limestones while the limestone has its shale intercalations.

Local intercalations, or even apparent super-jacent exposures of thin sandstones pebble beds and sandy flags, or lydian stone bands, are exhibited at places; the latter occurring to the north-east of Bilaspur about Norgoru, and the former to a very wide extent in the Raipur country, or on the Mahanadi near Chandarpur, or in the low Sai Dongri group of hillocks towards Padampur.

A curious, and as yet stratigraphically unsettled, outcrop of apparently higher

sandstones and extremely coarse conglomerates occurs on the right bank of the Mand where it crosses the plain before joining the Mahanadi, as the Girgiri and Tundri ridges. These low hills lie in a sort of broken chain, with intervening stretches of low country, between the Gida hill on the north and the long north to south Dadarpali range on the right or south bank of the Mahanadi. Mr. Medlicott surmised that these outcrops might be northerly prolongations of the anticlinal roll in the Dadarpali range; but a closer examination of them seems to me to point to their being portions of a crushed synclinal which might be expected as a complementary hollow wave in the strata on one side of the hidden portion of the anticlinal exhibited in Dadarpalli and the southern end of Gida hill.

In the first place, it is really only by the merest chance exposures that rock is seen *in situ* in these ridges, for they are to all appearance made up entirely of loose well-worn pebbles, shingle, and largish boulders of various kinds of quartzite, quartz-schist, and some crystalline rocks. The whole facies is that of great shingle banks formed in comparatively recent times alongside the bank of the Mand river: even the tops of the ridges consist of loose debris. However, I found good hard quartzite sandstone and conglomerate in a small cross valley north of the Govindpur peak, obscurely bedded but apparently vertical and striking north to south. Again on the extreme north end of the western Tundri ridge, there are coarse pudding-stones, having a hard purple clay-stone matrix, which are traceable along the crest of that part of the ridge into massive heavy conglomerate rock having no definite bedding. The pudding-stone is very obscurely associated by super-position on the red-purple shales forming the slopes of the ridge the dip of the latter being 40° to 50° eastward. The main portion of this western Tundri ridge shows no bedded rock, but it has its steeper side to the west. The eastern Tundri ridge, on the other hand, looks to have a westerly dip, and this agrees with the lie of the shales and gritty beds in the plain at its northern end.

The shales and limestones in the plains below these ridges have never been traced into actual contact with the sandstones, though they are often quite close enough to accentuate the fact that on both sides their dip is rolling and inwards towards the ridges; while at the north end of Girgiri, by the village of Bailagarh, the shales strike round east–west and dip southwards.

All these conditions point, I think, to the preservation in a couple of ellipsoidal hollows or synclinal waves of a remnant of overlying sandstones; the southern or Girgiri synclinal being in an extreme state of crush. Looking at the rapid change from heavy conglomerate to scattered pebble bed or pudding-stone at the north end of the west Tundri ridge, it would appear as though their extremely coarse detrital constitution may after all be only a very local development in an insignificant sandstone band, the lateral extension of which may be indicated by the occasional outcrops of sandy flags and pebble beds occurring in the limestones and shales to the westward in the valley of the Baghar stream; or it may be an extension of the sandstones in the Sai Dongri hillocks near Padampur. Mr. Bose has also indicated a large spread of sandstones in the Raipur country, overlying, to all appearance, the limestone group; and the Girgiri beds may be related to these. There is, of course, no certainty that these various and

detached sandstone occurrences are of one and the same band, or even that some of them are not merely local intercalations with the limestones; so that it would be rash to conclude that the Girgiri conglomerates or the Raipur sandstones belonged to a further and superior member in the series; at the same time there are evidences of the possibility of such a succession in the detached area of Vindhyans, near Nawagarh, to the south of this basin, described by Mr. Ball in his papers on the "Mahanadi basin and its vicinity."[1]

Chilpi beds.—At the north-west corner of the basin, the route from the Bilaspur plains to the Mandla plateau goes by the Chilpi ghât; and as it was on this pass that they were first examined, the rocks now to be treated of may, for present convenience, go by its name. Mr. Medlicott has suggested the possibility of their being of lower Vindhyan age, and as either lower than or partially representative of the sandstone member of the Chhattisgarh series. It was thought that Mr. Bose's examination of the western side of the basin, in the Saletekri range and its slopes, in so far as it took up a southerly continuation of the Chilpi rocks, would have cleared up all difficulties or obscurities in the way of settling their relations to the rocks of the plain; but, as already hinted, that examination was not sufficiently exhaustive. My march into Mandla, at the end of the season, gave another opportunity of examining the ghât section; and this experience taken in connection with what I had already seen *en passant* at Ratanpur and about the Soti hill, enables me to connect in a distant way, the rocks of both areas and compare the relations of each with the plain series.

As far as the Chilpi ghât and its immediate neighbourhood are concerned, there is no contact section: the strata of the foot-hills are separated from the limestones and shales of the plains by a belt, a mile or so in width, of alluvial deposits, and such seems to be the condition of obscurity all the way southwards along the western edge of the plain. Taking the section along the road to Chilpi from Borla village on the edge of the plain; the traveller's dâk bungalow is built on grey or pale flesh-colored hard quartzite sandstones in strongish beds, somewhat pebbly and conglomeratic which are here exposed by denudation as a roll up from under the limestones and shales of the immediate neighbourhood. The small temple hill in the village consists of these latter rocks; and to the westward there is about a mile width of alluvial deposits. The road then rises gradually from the alluvial flat over brown and buff-weathering clay-slates, internally of dirty dark green color, constituting the main mass of the first ridges or foot-hills, their strike being about north-east–south-west, with a rolling or undulating general dip to north-west. To the southward of Borla, about the neighbourhood of Chahata and Gungho, just within the edge of the plain this strike has a more southerly trend; and here the clay slates are overlaid by thin sandstones and gravels with a rolling easterly dip, though, as usual, there is the tantalizing blank of alluvium and cotton soil between them and the limestones out in the plain of Minminia. Chahata is on dark-green, reddish-brown weathering, coarse clay-slates, and these are tolerably well traceable towards Gungho where they gradually become overlaid by rolling yellow and buff sandy and clayey shales, which in their turn are succeeded by thin sandstones and gravels, having an easterly dip.

[1] Records, G. S. I., X, p. 172.

The difficulty is to say decidedly whether these shales come in over the clay-slates in conformable or unconformable succession; for the lie of the latter is not well displayed, and they could easily have rolled over from their high westerly dip at Chahata. My own opinion is that the shales and sandstones are unconformable, and they certainly do look very like the thin gravelly and shaly bottom beds at Ratanpur, and on the Hasdu.

Taking up the road section again; it crosses the foot-hills by a winding course to the open valley of the Banjari stream, always over dark-green clay-slates (weathering buff-brown and reddish colors) with which are associated subordinate beds of harder compact claystone and—less frequently—beds of hard sandstone (quartzite) much stringed with white quartz. Similar rocks, with perhaps coarser and more sandy cleaved shales, sometimes weathering a bright ferruginous red, fill up this valley and constitute the greater part of the ridges on its western side, and beyond this occur traces of hard green quartzose beds, or grits, full of particles of white quartz and felspar or larger sub-angular fragments of granitic and crystalline debris. Then, at the foot of the old ghât or pass up to Rajabdar are massive, granular, and somewhat porphyritic green-stones, and red and green mottled brown trappoid rocks, in somewhat banded outcrops and apparently striking with the green quartzose grits, and slaty strata even higher up the pass.

The strike over all this ground is about north-east–south-west, and the dip appears to be generally north-westward, though rolling and folding almost amounting to reduplication are evident. Towards the foot of the old ghât, however, the strike trends round to nearly north and south.

Following up the Banjari stream towards Palak, the change of strike becomes more quickly developed, until at the camping place it is south-south-east to north-north-west, with east-south-east dips. Here, too, there is a decided and sudden change from the clay-slates of the foot-hills to what would appear to be—from the dip—an underlying band of hard massive green white-speckled grits, associated with coarser and more massive cleaved shales and shaly grits, and clay slates. The speckled grits become, as the strike is crossed against the dip, coarser and coarser in their contained debris, until a thick and strong band of hard, but irregularly-bedded, extremely coarse and heavy conglomerate is reached, which is best seen in the river north of the road. This band is a closely packed but very obscurely bedded mass of well-worn, rounded, sub-angular and angular fragments of various kinds of quartz, quartz-rock, quartzose rock, or fine quartzite and quartz-schist, hard green shales and cherts, through which are scattered small pebbles or rounded masses of white felspar. The speckled green grits above it are fuller of bits of white quartz and felspar; and when they are very fine grained and compact, they certainly have a sort of igneous look. Below, or to the westward of the conglomerate band, are further dark-green massive slaty bands, with softer slates at intervals, and there are also frequent outcrops, perhaps repetitions, of the white speckled grits. Towards the foot of the main ascent of the ghât, indications of a lower easterly dip are frequent, and there is some undulation among hard thick-bedded massive slaty quartzose rocks. Next comes a long display of trappoids and dark-green massive trap or greenstone; giving perhaps an

exaggerated view of their possible thickness, as the road keeps a good deal on what may be their strike, if they are associated in this way with the more manifestly bedded rocks of the foot and upper part of the pass. Near the top a heavy conglomerate, exactly like that below at Palak, occurs with a westerly dip; and this rock is succeeded by the Lameta limestone and the overlying basalts of the Deccan series.

On the plateau, the basalts, after some distance from the edge, and to the north of Rajahdar, have been denuded along the valley of the Phen river, until the thin underlying Lametas again become exposed; while further down the valley there are occasional outcrops of a strong conglomerate answering exactly to that at bottom and top of the ghât. Thence westwards to Motinala, clay slates and green quartzose and compact schistose rocks are prevalent. Schistose micaceous sandstone flags occur in the bed of the stream below Motinala, with a dip of 5° north-west; and similar sandstones and slaty shales are common in every small water-course of this small valley, rolling about at all angles.

So far the Chilpi facies is clearly recognizable; but somewhat more generally schistose, hornblendic and micaceous rocks come in over the Halon valley and extend to the Bichia basalt plateau, without however any sudden change, or any more steady strike or lie. On the other hand, in descending from the western edge of the Bichia plateau to the Anjania valley, the more generally massive and crystalline gneissic rocks would indicate that the limit of the Chilpis had been passed.

In reviewing the lithological and stratigraphical conditions exhibited on the Chilpi ghât, as well as over the area of what are manifestly the same set of rocks westwards towards the Hasdu river, or again southwards in the Saletekri ridge, it is difficult to avoid noticing certain points which seem to militate against the relation suggested by Mr. Medlicott as existing between them and the Lower Vindhyans of the basin.

In the first place, the Chilpi rocks have a decidedly different facies to those of the plain and its proper rim, while they seem to pass gradually or without a break into more and more thoroughly sub-metamorphic rocks. I do not, however, here lose sight of the fact that in Mr. Medlicott's Lurmi section, the junction between the crystallines of the Khathar hill and the slates and shales on its southern flanks is comparatively sharp.

2. There are rocks on the Chilpi ghât which can be very closely matched by those of the Ratanpur 'old city' hills and the Soti hill, where as I have already described, there seems to be a transitional facies emphasized by a strongly discordant relation with the bottom sandstones of the rim of the basin.

3. The Chilpi series occupies a broad tract of country, and though this may be shewn to narrow down in a gradual way to the Hasdu river, the strange fact remains—supposing they are Lower Vindhyans—that it should come in in such a marked and rapidly thickening manner at one side or corner of the basin either from under, or in association with a thinning out of an essentially sandstone group which has been over the remaining two-thirds of the basin edge the absolute basal member of the Chhattisgarh Vindhyans.

4. Although there is no known occurrence of the thin band of bottom sandstones (with shale intercalations) on the Chilpi ghât itself; an apparent

representative of them occurs to the south of Borla overlying, I think unconformably, the green clay slates of the foot-hills. Similar sandstones have been recognized still further to the south, but under the disadvantage of not as yet having been clearly distinguished from other sandstones which are associated with the slates and trappoids in the Saletekri hills. Nevertheless these questionable occurrences have some value in this stage of the enquiry, in so far as they lend color to the expectation that a distinct and recognizable thin sandstone representative of the Chandarpur beds may exist all round the western side of the basin.

5. The apparent parallelism of strike in the rocks of the plains, and in those of the foot-hills, can be accounted for by north-westerly crush of the easy-lying basonal beds against a series which may have already had somewhat of the strike exhibited in the Lurmi, Chilpi, and Saletekri slopes.

There are other exhibitions not unconnected with the Chilpi rocks which might be referred to now; such as the occurrence at Sakoli of coarse conglomerates, trappoids, and green rocks in the extreme southern spurs and prolongations of the Saletekri hills, already known through the work of Messrs. Blanford and Ball,[1] but they have not been connected up with the present work.

I may point out, however, that Mr. Bose has mapped in a tract of rocks on the southern edge of the Raipur part of the field, separated entirely by crystallines, from those of the Saletekri hills, near Khussumkassa, which he considers representatives of the Saletekri, or in other words the Chilpi series. The awkwardness of this occurrence is that the relations of the bottom sandstones of the basin edge to those underlying rocks are not sufficiently displayed, or closely enough described by Mr. Bose, for the acceptation of the unconformity which might be inferred.

The relations of the Chilpi series and the proper Chhattisgarh Vindhyans must therefore still remain an open question; and though I have tried as well as I could to put forward some of the points which strike me as not satisfying the requirements of Mr. Medlicott's suggestion, it will be safer to hold by it until better evidence can be accumulated.

LOWER GONDWANA.

The general limits of this formation in the present field have been long known through the work of Messrs. Medlicott, W. T. Blanford, and Ball, and papers by the two last authors on the numerous coal-fields have appeared from time to time in these records. Thus our later work has been little else but the filling in of unsurveyed intervals, or the ascertaining of details.

A remarkable physical feature in this region, paralleled in many other Lower Gondwana areas, is the generally straight south-western boundary, extending as it does with tolerable precision from the neighbourhood of Korba nearly down to Sambalpur. It is not proposed here to enter further into the general discussion as to whether such straightness of boundary is due to faulting in great part, or merely to deposition in a straight-sided valley or basin; but, as bearing upon the local feature, the fact of the occurrence of a small and hitherto unknown area of

[1] Records, G. S. I., X, p. 180.

Talchirs and Barakars actually within the Chhattisgarh basin is of considerable interest.

This outlier occurs on the eastern flanks of the Gida hill, and being in the plains, is at about the same level as, or very little lower than, the proper Mand valley coal-field to the north of the river pass. It occupies an area of about 5¼ square miles; the Barakars, which are in contact with the Vindhyan sandstones of the hill, taking up about half the space, while the Talchirs hade out from underneath them and fill up the remaining half, the latter resting on the red purple shales of the plain. Both groups are well displayed in the vicinity of the village of Kunkuni, lying with an easy dip of 5°—10° west-south-west. Actual contact of the Barakars on the Vindhyan sandstones was not found, but the junction is so close at the southern end where the Balu stream issues from the central valley of the hill mass, and the baying-in of the sandstones over the easterly dipping quartzites is so clear that natural and easy contacts cannot be doubted.

The Barakars resemble very closely those of the Raigarh-Hingir country, but without any trace of coal that I could see, and they have near the base the same ferruginous flaggy and clay-stone band, giving lateritic weathering, which, here too, is worked for iron by a colony of *lohars*. The Talchirs are the usual greenish silts or very fine sands with occasional boulders of gneiss and quartzite, and at the southern end of the field a local exhibition of fine pale-yellow or buff sandy shales occurs in a bend of the Balu stream.

I will not go so far as to suggest that this little field was once connected with the main area to the north; indeed, the character and lie of the rocks in the river gorge is rather against such a view: but there is no doubt that the conditions of deposition and subsequent movement must have been much the same in both areas, as well as in the more distant area of Talchirs and Barakars to the eastward in the Sambalpuri-Kodibuga valley near Raigarh. The only difference in the occurrence of the groups in the latter region is that the Talchirs are not exposed on what may be called the off-side with regard to the Vindhyan sandstone edge, but crop up at intervals where the Barakars have been denuded on the inside or next the hill ridge: but this does not alter the fact that here, as on the flanks of the Gida hill, the Barakars simply overlap natural-lying Talchirs by thickness of deposition against a rather steep wall of more ancient rocks. My examination of the Sambalpuri valley was very close, and it soon became evident that the boundary where the Talchirs are seen in close juxtaposition with the Vindhyans is not straight but wavy, and delineatable (to coin a word) as such on the 1-inch map. Indeed, if general straightness were to be taken as at all conclusive of faulting, it might be doubted whether the straight limitation (always covered up by alluvium) between the Kamthis and Barakars on the opposite side of this narrow valley were natural. The turning up of the Talchirs at low angles along the skirts of the Sambalpuri ridge of quartzites is, at the same time, really not more than is consistent with the peculiar filling-up and banked style of very many curious Talchir exposures, yet to be noticed, in other parts of the field.

Talchirs.—Further survey has marked out a strong development to the northward of Korba town, in the Chhuri, Mahtin, and Uprora zemindaries, and on

north-eastward into Sirgujah by Lakhanpur. On the Chhuri and Mahtin side, the formation fills up the bottoms of several long and deep valleys running between high hills of gneiss, while there are also outlying patches of the characteristic silts and boulder-bed on the hills and uplands; and in this way the intervals—if indeed they do exist—which separate the Mahanadi tract of Gondwanas from that of the Son in South Rewah must be very short. In Uprora, the Talchirs are continued eastward and north-eastward by a narrow fringe bordering the northern edge of the Phutka mass of hills, and thence below the steep slopes of the Lakhanpur plateaus.

The thickness over this part of the country is very unsteady: and the presence of boulder-bed, or fine laminated shales, or fine silty sandstones is equally capricious. The floor of crystallines is most rugged and uneven; valleys, ravines ridges and bosses of these rocks having been filled up or covered over until the more even surface was produced upon which the succeeding Barakars were deposited. To the north-eastward, or at the foot of the Dulapur (3,169 feet) and Jaun (3,197 feet) range, the fringe is very narrow and of little thickness; but further south or below the Samar (2,411 feet) cliffs, the boulder-bed and fine uneven-bedded sandstones are well spread out over the Arsena upland, with a most variable thickness, evidently filling up hollows which were as numerous and deep as the existing valley system of the head drainage of the Gandhar stream. The Arsena display is very curious and puzzling, for one could not be always sure that the frequent occurrences of very large masses of gneiss and granites were not *in situ*, or that the extraordinary amount of gravel and shingle associated with them was not merely Talchir debris. However, one soon meets with almost as frequent big masses of quartzite sandstone; while the different lithology of the crystalline masses becomes apparent: and in the end similar blocks are seen embedded in the fine silty sandstones forming the very steep sides of some of the minor valleys.

As usual, there is no fixed horizon or level for the coarser or finer forms of deposition: fine sandstone, shales, or boulder bed may be met anywhere in the ravines or on the shoulders of the downs or rounded hills of this tract; and the general facies is that of irregularly banked-up accumulations of fine silts, shales, or boulder bed having only very local lamination or signs of bedding.

The small water-course rising on the Arsena side of the remarkable crystalline ridge (with a dyke core of basalt), gives a fair display of the Talchirs as it flows down towards Lemru. The bottom rocks, plastered as it were over the crystallines, are blue-green silts and shales full of pebbles and big boulders of all kinds of quartzite sandstones, hardened shales or clay-stones, and crystallines, not crowded together but scattered at irregular intervals. There is no steady lamination or bedding, merely a sort of inconstant or wavy arrangement indicative of irregular and interrupted sedimentation. The boulder banks are overlaid or succeeded by yellow-green and buff sandy shales—still holding a few boulders—which in their turn shade up into a very thick accumulation, sometimes bedded, of yellow and greenish sandstones. These last are succeeded by coarser sandstones, but without any passage being seen in any exposure that I could find, which must be taken as Barakars. The low ridge immediately south of Arsena, for example, has its summit

of thin-bedded brown ferruginous sandstones and grits of the lower Barakar type of the Hingir coal-field; but they come in quite gradually and naturally over the Talchirs.

Between Lemru and Deopani to the west, the out-crops of huge masses of gneiss in the fine buff sandstones are so strong at times that some of them can hardly be other than knobs or crests of irregular ridges, once more exposed through denudation of the Talchirs; and this form of occurrence is not so strange when the conditions of the very remarkable system of east-west crystalline and basaltic ridges in Mahtin and Uprora is considered. The crystalline ridges undoubtedly stood out very much, as they do now, in Talchir times; for silts, boulder bed, and sandstones can be seen in both regions lying flush against the base of some ridges, even on both sides; as is more particularly the case in the valley to the north of Uprora, and in the two long and narrow valleys leading westward from Mahtin to the Pendra upland: but the basaltic dykes forming some of their cores are of later age, for in other parts of the field they cut right up through the Gondwanas into contact or junction with the overlying Deccan trap.

The lie of the formation is generally very easy; but the different elevations within short distances, at which one finds bottom deposits, are apparently so great that it has been thought necessary by previous observers to call in more than ordinary elevatory forces to account for them. The highest show of Talchirs in this field is on the Rer valley, near Meria, at about 2,500 feet over sea level, while the nearest low-lying tracts of the same rocks are on the head-waters of the Mand near Rakhob, at an elevation of about 1,000 feet, with an interval of about 19 miles horizontal; or in other words with a fall of 1,500 feet in 19 miles. There is undoubtedly some faulting in the neighbourhood of Rakhob, but an average dip of not more than 11° is all that is required to carry the Talchirs of the Mand up to their elevation on the Rer. Much sharper differences of level, though the absolute height is not so great, are frequent, according to the observations recorded by Sub-Assistant Hira Lal, in the Chhuri and Mahtin country; but these are all, I think, explainable on the peculiar filling-up tendencies or ballasting powers of a ground-ice, or floating-ice formation such as the lower portion of the Talchirs appears to have been.

The puzzle about the formation here is to say where it ceases in an upward succession, or at what stage the overlying Barakars come in: all that one can be sure of is, the being on Talchirs of the more typical form, or on Barakars of well-known and widely distributed type; and thus the boundary between the two is to a large extent arbitrary, though after all it cannot be far out on either one side or the other. I was enabled to follow the succession with fair closeness at two points: first along the bed of the Kesla tributary of the Dhongur river on the south-west skirts of the Phutka mass of hills in Korba; and next, down the Katora pass, from the Sirgujah high-lands to the lower upland of Uprora, in the extreme north-east of our area. I was on undoubted Barakars with coal seams in the Kesla stream, and in following its course downwards, I passed, without once losing sight of rock, insensibly from great thick-bedded pot-hole-worn sandstones to finer and finer-grained thick beds of greenish-yellow and buff sandstones almost like some varieties of Talchir sandstones. Then after a blank of

alluvial deposits, the next rocks seen lower down the river towards Risdu are silts and the boulder bed. On the Katora pass, the interval between the undoubted boulder-bed and silty flags at the bottom near Bahue and the thick-bedded fine yellowish or buff sandstones of the lowest run of cliffs is much shorter; but it is covered, as usual, on that side of the country by a talus of debris which has gathered below these cliffs.

One other but isolated occurrence remains to be noticed of Talchirs and Barakars in tolerably close contact. On the head-waters of the Rer river, that is, on the upland to which the Katora pass leads, about the villages of Kesura and Merua, Mr. Ball had already distinguished Talchirs, or rocks which he considered lithologically undistinguishable from them. There can be no doubt as to their occurrence here, but the boulder bed is in such close and abrupt juxtaposition with thick-bedded fine sandstones of the type indicated in the last paragraph that the junction has certainly an appearance of unconfirmity about it. Unfortunately, I was here struck down with a sharp attack of fever which necessitated my marching out of the valley as soon as I could be moved, so that the clearing up of this point remains over for a later visit.

Barakars.—This formation is fairly distinguishable over most of the Korba, Mand, and Rer regions, while it possesses the valuable characteristic of being coal-bearing in several localities. Ball had already followed it out over the east side of the Mand valley and Blanford had traversed the Korba field; while I have closed in the country between, carrying the coal-bearing horizon into the lower portion of the great Phutka hill block. There is no difficulty about recognition on the south, south-eastern, and eastern flanks of the mountains, where the slopes are long, giving good exposures of typical rocks; but it is not at all so easy to do this on the steep-cliffed north-western frontage, for in the first place, I failed to get a trace of coal or carbonaceous shale, and the rocks themselves are not so clearly of the *Barakar* type. It turned out, however, that the lower line of cliffs is made up of thick and fine-grained beds like those of the lower reaches of the Kesla river, and the bottom of the Katora pass already referred to; and that the more usual form of Barakar sandstones is higher up in the cliffs or rather in the short terrace between the two tiers of cliffs, generally marking the north-west faces of the range. The key to this interpretation is afforded by the succession of strata as exhibited in the Mand valley below the western slopes of the Phutka range, particularly on the Bijakharra and Labed streams. In these sections a fairly well-developed seam of coal and carbonaceous shales is overlaid by softish fine-grained yellow or buff sandstone, dashed here and there with sheets of salmon and red colour. High bluffs of this form of rock occur every now and then at the sharp bends of the stream, sometimes 50 feet in height, without a single bed parting; or if there be such, it is only for short distances. Often there is just a thin bottom layer or bed, 6 to 8 inches in thickness, coming in over the blue and grey shales of the coal seam. The features of this variety of Barakar sandstones are thickness of bedding and fineness of texture. Up above and for some distance in from the face of these cliffs the rock is so soft and devoid of any trace of lamination that it might be taken for a semi-hardened or cemented form of superficial deposit. In the Bijakharra river above the Kulgao-Phulsari crossing, one may walk for a mile or so over coal and

carbonacious shales with the superincumbent thick-bedded, even-textured, fine-grained buff and yellow red-dashed sandstones rising up in clean cliffs on either side; and still further up, these are gradually succeeded by massive coarse and pot-hole-worn sandstones of the type so prevalent in Hingir and in the Wardha and Godavari valleys.

This soft lower member is traceable on northwards to Amaldiha at the head of the Mand valley, and is recognizable again in the Matringa valley of the Sirgujah upland on the head-waters of the Rer. Indeed, the constitution and texture, and fair horizontality of these rocks has contributed greatly to the peculiar terraced contour of the bottom of the Matringa valley: the steam runs in what looks exactly like a terraced alluvial plain at the bottom of a long and wide mountain valley, but the terrace is of these soft Barakar rocks which give the 30 to 50 feet step to the proper river plain. The villages of Matringa, Merua, &c., the cultivated lands, and all the beautiful stretch of *sal* jungle are on this terrace and overlook as from a vantage ground the lower flat with its winding river. Similar strata terrace the valley of the Borki tributary of the Rer to the westward, up which the road to the Katora pass runs; and over that pass and down its western slopes in the Bahue valley the same beds are again found forming a terrace step and cliff descent of nearly 200 feet to the underlying Talchirs.

Kamthis.—The Barakars of the basal portion of the Phutka range are gradually succeeded by a great thickness of more open-grained coarser-textured and often pebbly, generally white or purple-streaked felspathic sandstones, with frequent intercalations of white clays, in moderately thick and well-defined beds; the only sign of a break or passage being the occurrence of a badly-defined band of varying thickness of brown-weathering ferruginous sandstones which may be taken to represent the more generally surface-exposed tracts of red and brown Kamthis in the Hingir-Raigarh country. The pale colour and wonderfully pebbly constitution of the upper strata led me at first to suspect that the higher parts of the hill mass might turn out to be of Upper Gondwana rocks; but the occurrence of much crushed, though recognizable, specimens of *Vertebraria* in the white clays of the Guarduari (3,250 feet) hill effectually stopped this expectation.

That the brown ferruginous band of sandstones marks the basal portion of the Kamthis in the Phutka range, is pretty evident from the fact of Mr. Ball having been able to distinguish his Hingir or 'upper sandstones' (*Kamthis*) up to and across the Mand river, as far as the little Gumar plateau; and from my having carried the same rocks into the larger Jobi plateau and thence after an intervening plain of *Barakars*, into the Kakaigadra (1,602 feet) group of low hills, about Nunbira and Sendrapali, forming the extreme end of the southern spurs of the Phutka range. Similar brown sandstones make up the lower parts of the loftier Raka and Bitrahi group, and are there succeeded or overlaid by paler-coloured white or purple-streaked open-textured and coarse pebble-seamed beds with white clay intercalations, containing *Vertebraria*.

I did not come across any section showing actual contact of the Kamthis on the Barakars, but there always appeared to be perfect conformity between

the two. On the other hand, overlap is very clear at this southern end of the Phutka spurs, there being only a very narrow strip of Barakars in the Sendrapali and Dongama plain below the low Kamthi scarps of the Kakaigadra range, and this is edged on its south side by a thin fringe of Talchirs next to the rising ground of crystallines on the flanks of the Pipra ridge.

The apparently diminished ferruginous element in the Phutka Kamthis is very marked; while there is little, if any, sign of the red clays so common in the Hingir country. This may arise in great part through insufficient exposure and denudation, or from the overpowering influence of the greater thickness, sometimes in great scarps, of lighter or paler coloured rocks, and the very large amount of their debris scattered over the lower slopes. It must also be remembered that the best exhibitions of ferruginous strata and red clay bands must necessarily be where denudation has laid bare extended plateau surfaces of those particular members, as is the case in the Hingir country. A rather prominent form of debris, scattered about the skirts of the Phutka range, consists of huge fragments of a pale-red clayey form of laterite which seemed to point to the existence of red clay bands; but this soon turned out to have fallen from the capping of laterite, or a lateritized form of weathered trap occurring on many of the loftier flats of this mountain mass, at levels of from 2,000 to over 3,000 feet.

At the same time, there is an almost absolute thinning out of the lower brown ferruginous member on the northern flanks of the Phutka range, or more especially in that deeply eroded portion of it joining on to the Sirgujah plateaus overlooking the Rer drainage. I always passed on that side of the country, wherever there is a gap in the hills, from Barakars of the fine-grained type to coarse and harsh open-textured grey or pale buff and white purple-streaked sandstones, having frequent seams of gravel and large pebbles of white or glassy quartz, without seeing a trace of the harder brown beds.

Boring Exploration in the Rampur Coal-Field.—The most important practical feature of the great tract of Lower-Gondwanas fringing the eastern side of the country treated of in this paper, is of course the occurrence of coal at several points. The thick carbonaceous outcrops of Korba are well known as giving promise of fairly good fuel, but the place is still far out of reach of probable railway traffic. Then, again, the Mand Valley gives very favourable exposures at several places, as in the bed of the Bijakharra stream already referred to, or at Amaldiha at the northern end: only in these cases, also, the present inaccessibility of the region is against all prospect of development.

At the south-eastern extremity of the area however, within about 40 miles of Sambalpur, the rather large field of Hingir, reported on so many years ago by Mr. Ball,[1] lies right in the track of the proposed Chhattisgarh railway, under which circumstance its development becomes as it were a necessity. I was deputed to examine this field during the season before last with a view to selecting sites for boring, the results of my survey being given in the Records of August 1884 (Vol. XVII, p. 123). An Assistant Mining Engineer, Mr. T. G. Stewart, already favourably known through his borings in the Narbada Valley

[1] Records, VIII, p. 102.

and at Umaria, in South Rewah, was then placed under my guidance by the Central Provinces Government. I had divided the rather large and somewhat unapproachable area into several sections, the most favourable, as far as contiguity to the railway trace is concerned, being that on the valley of the Lillari, partly in Hingir and mainly in the Rampur zemindari; and it is on this that the boring exploration was commenced in what is now officially designated the Rampur Coal-field.

All the surface indications point to the probable occurrence of two rather thick bands of carbonaceous deposits, the lower—some 50 to 60 feet thick—being well displayed in the river near the village of Durlipali, while two outcrops of coal higher up the stream, about Bonjari and Kuliabahal, point to the upper; and as it appeared to me that the latter outcrops are more promising than that of Durlipali, and that it would be possible to strike their coal by bore-holes within a convenient distance of the proposed railway station at Hingir road, I determined to try this band first.

The borings were selected near the villages of Girandola and Chowdibahal on what I took to be—for much of the rock is covered by superficial deposits—either the uppermost beds of the Barakars or the lower red-clay zone of the Kamthis. As it turned out, all the borings, six in number, were started in the red-clay zone, through a greater or lesser thickness of which five of them were run down into the carbonaceous band beneath. Two of the holes were abandoned, but four were run down to depths varying from 225 to 287 feet. These four bore-holes (Nos. 1, 2a, 3, and 4) enclose a sort of triangular area of about half a square mile in extent: No. 1 being at the southern apex, No. 3 nearly a mile due west of it, and No. 2a being about half-way between the two; while No. 4 lies more than half a mile northward of No. 1. The dip of the strata is low to north-westward, perhaps just here rather more to the west-north-westward; occasionally, indeed, it must be quite flat, or nearly so, though it is mostly at an angle of from 5° to 10°. No. 1 bore-hole was run down 225 feet right through the upper band of carbonaceous deposits, or, at any rate, a good part of it which it entered about 30 feet from the surface and left at 219 feet when the chisel began to cut into white sandstone. Three seams of 6, 8, and 4 feet of coal, besides others of inferior thickness, were met with in this band; but though the samples brought up were favourable-looking enough, laboratory assay proved them to be quite unfit for railway purposes. That taken from the 6-foot seam, at 77 feet from surface, gave the following analysis :—

Moisture	10·00
Volatile matter, exclusive of moisture	24·50
Fixed carbon	29·90
Ash	35·60
	100·00

Does not cake.
Ash, pale-yellowish brown.

Another sample from the 8-foot seam, at 142 feet from surface, assayed foot by foot, gave the further depressing result.

	$\frac{142}{1}$	$\frac{142}{2}$	$\frac{142}{3}$	$\frac{142}{4}$	$\frac{142}{5}$	$\frac{142}{6}$	$\frac{142}{7}$	$\frac{142}{8}$	A well mixed sample of Nos. $\frac{142}{1-8}$.
Moisture	11·08	10·58	12·00	11·02	9·40	7·44	8·04	13·38	9·98
Volatile matter, exclusive of moisture	22·14	21·26	22·66	22·06	20·52	19·00	18·60	23·84	21·22
Fixed carbon . . .	27·08	25·70	28·36	26·42	24·04	19·48	20·32	32·90	24·62
Ash	39·70	42·46	36·98	40·50	46·04	54·08	53·04	29·88	44·18
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake. Ash, pale-yellowish brown.	Does not cake. Ash, pale-yellowish brown.	Does not cake. Ash, muddish brown.	Does not cake. Ash, yellowish brown.	Does not cake. Ash, muddish brown.	Does not cake. Ash, muddish brown.	Does not cake. Ash, light brown.	Does not cake. Ash, yellowish brown.	Does not cake. Ash, muddish gray.

In the meantime, that is, while these assays were being made, the other bore-holes were being carried out; and further samples from them of what appeared to be the same seams were discarded through showing no signs of improvement, or sent down to Calcutta. Among them, the following scarcely better result was obtained from a 6-foot seam in No. 4, at 69 feet from surface, the seam indeed which appears to correspond to that at 77 feet in No. 1, 174 feet in No. 2a, and 183 feet in No. 3; in all of which and in the continuations of the other seam of No. 1, we failed to strike any better coal.

No. 4, 69 feet from surface, seam 6 feet thick; foot by foot.

	1	2	3	4	5	6	A well mixed sample of Nos. 1-6.
Moisture	12·42	9·96	12·20	13·18	13·08	12·86	12·44
Volatile matter, exclusive of moisture . . .	26·40	24·92	26·10	26·90	26·86	26·82	25·86
Fixed carbon . . .	34·12	27·88	32·92	37·00	36·98	35·74	34·66
Ash	27·06	37·24	28·78	22·92	23·08	24·58	27·04
	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake. Ash, red gray.	Does not cake. Ash, pale red.	Does not cake. Ash, red gray.	Does not cake. Ash, pale red.	Does not cake. Ash, red gray.	Does not cake. Ash, pale red.	Does not cake. Ash, pale red.

There seems no doubt whatever but that the upper 6-foot seam is fairly constant in thickness, and, unfortunately, in quality also throughout the area tried. The still lower seam of 8 feet at 143 feet in No. 1 hole appears also to have been struck at 221 feet in No. 2a; 248 feet in No. 3, and 128 feet in No. 4; but it is not at all so constant in thickness or so even in constitution. The lowest seam in No. 1 is apparently represented in No. 4 by a 4-foot seam: there is no improvement in quality.

It may seem rash to judge, from so small an area as that now bored, of the probable or possible condition of the lateral extension of the seams so proved; but considering, as I do, that some of them represent the upper outcrops on the Lillari river, I think I am justified in arguing concerning their condition from a really much larger area than that merely included within the three corners actually tested; and so from what they and these outcrops show, and from what I have seen of the rocks round the eastern skirts of the Hingir plateau, the conclusion is forced upon me that there is no fair ground for hope that the seams of this upper band of carbonaceous deposits can improve laterally or to the deep within a workable depth (for Indian collieries) in this Lillari section at any rate.

There still remains, however, what may be a considerable thickness of Barakars between the horizon now reached and the lower band of Durlipali, in which there may be workable seams; and this must now be searched. For instance, the horizontal interval of country between the Bonjari outcrop and that of Durlipali is a long one, fully 2 miles, which, if the lie of the strata be at all regular and constant, would at so low an average angle as 8° give 1,450 feet of rock. At the same time, from all that can be seen of the behaviour of the rocks in the neighbourhood, the indications seem to favor the conclusion that there cannot be such a great thickness: and that the Durlipali band is carried under the Bonjari horizon at a somewhat lesser depth by an anticlinal or arched wave of the strata. It is possible, therefore, that an idea of the quality of any lower seams will be ascertained by the new bore-holes at a lesser distance south-eastward of the now proved tract than the interval and apparent dip would imply.

DECCAN TRAP SERIES.

The coarse pale-colored upper member of the Kamthis in the Phutka hill mass and the high plateaus on the edge of the Sirgujah upland were pared down by denudation to a tolerably even surface on which the basalts of the Deccan trap period were subsequently laid down. Only small remnants of this basaltic covering now exist in the area under consideration, and these are entirely separated by a long interval of crystallines from the great connected area of this formation, the eastern extremity of which is at Amarkantak. Mr. Ball had already mapped in some of the basalt cappings of the plateaus around Matringa, and I have added to these: he also noted the occurrence of trap dykes about Amaldiha and Rakhob at the head of the Mand valley. The trap cappings are not very thick, 50 or 60 feet at the most, but they consist also to a certain extent of laterite the true relation of which to the basalt is not clear and must be worked out perhaps on the larger plateaus, such as the Main Pat immediately to the eastward of the Matringa valley. So far as I could ascertain, the upper portions of

the cappings are either laterite altogether, or only partly so; and from what I have seen of the laterite on the edge of the Mandla and Amarkantak plateau, it certainly seems to me that the rock here is in both regions very often, if not altogether, a lateritized form of weathered or decomposed basalt or other volcanic rocks.

The higher portions of the Phutka range were not traversed in any detail, so that I am not sure whether some of them may not be capped by basalt; but in the general absence of trap debris in the valleys I should question whether there be any of much importance. At the same time I know of a few cappings which are apparently altogether lateritic.

The trap dykes cutting along and up through the Gondwanas of the valleys and slopes are marvellous in their length and the height to which they run up the lofty slopes into what appears to be absolute contact with the basalt cappings. My observations of the junctions, owing to illness and lateness of the season, do not unfortunately possess that accuracy required for the complete settlement of the question of junction, the bearings of which on the question of the fissure eruption mode of discharge of part at least of the great Deccan flows is of the greatest importance. Nevertheless, I am inclined to be almost positive that the great dyke striking about west-north-west—east-south-east past Lemru, in Uprora, does actually cut right up through the Sumhaulata hill (over 3,000 feet) into junction with its basaltic cap. Again, in the Stump hill of the same group, the capping trap certainly appears to be in junction with a great buttress of similar rock standing out in clear relief from the lofty sandstone scarp on the eastern face, the buttress being also apparently continuous with a run of trap outcrops on the spur leading down to the Amaldiha dykes.

Report on the Bengal Earthquake *of July* 14*th*, 1885, *by* C. S. MIDDLEMISS, B.A., *Geological Survey of India.*

Introductory.

A preliminary account of this earthquake, by Mr. H. B. Medlicott, Director of the Geological Survey, has already appeared in the preceding number of the Records, briefly setting forth what inferences could be drawn concerning it from such information as was then at hand. Since then, from data personally gathered on the spot in the region of greatest violence, and from all available newspaper reports, I am able to put the following facts and deductions on record.

Extent of shock.

Taking its rise in Bengal, this earthquake of the 14th July was felt with violence throughout that province. It extended westwards into Chota Nagpur and Behar, northwards into Sikhim and Bhutan, and eastwards into Assam, Manipur and Burmah. The area over which it was sensibly felt may be roughly laid down as 230,400 square miles. An irregular ellipse drawn through Daltongunge (in Palamow), Durbhanga (in Behar), Darjeeling, Sibsagar, Manipur and Chittagong will give the external boundary of that area. Within this, again, another irregular figure may be drawn through Calcutta, Sitarampur, Monghir, Purneah, Siligori, the Garo hills, Chattack and Barisal, which will enclose an area over which the shock was felt

with such considerable violence as to shake loose objects, rattle windows, and produce small cracks in double-storied houses. Finally, we have another figure within this bounded by Rampur, Bogra, Sherpur (Maimensing District), Maimensing, Dacca and Pubna, where destruction to buildings is greatest and loss of life has occurred.

I shall now proceed to describe the results of an examination of the last-mentioned district, where it was hoped that some reliable data would be obtained, judging by the accounts of fallen chimneys, and fissured houses which had appeared in the newspapers.

Treatment of subject.

It is of course unnecessary for the purposes of a scientific journal to enter into lengthy accounts of damage to property and demolished towns, however great and terrible that loss may be; consequently it will readily be understood that such objects as are mentioned below are not chosen because of their size or magnificence, or because of the lakhs of rupees represented in their ruins, but, solely because either from their form, position, or from some other accidental circumstance, they best illustrate those points in connection with the earthquake which are of the greatest use to the scientific investigator.

In an examination of a country devastated by an earthquake, there is sure to be a great deal of evidence which at first sight appears to be contradictory, partly because of complications in the structure of the objects from which such evidence is taken, and partly because of the reflections and refractions of the earth wave, which hinder in some degree the search after the true centre of disturbance. And on the other hand, certain classes of objects, such as chimney-stalks, towers, temples, and tombs, by their form and isolation, are evidently much better suited for observation than complicated double-storied houses with verandahs and innumerable doorways, windows and arches. For this reason, I shall divide the series of examples of the effects of the earthquake into two groups; the first of which will comprise all the more trustworthy cases, and the second those of a more doubtful value, together with certain exceptional phenomena.

(I).—Examples of first importance.

Chimney-stalks of the Serajganj Jute Company.

On arriving at Serajganj, I found it to be one of the towns which have suffered very severely from the earthquake. It may not be out of place, for the benefit of foreign readers, to briefly state that the native town and the European houses in Eastern Bengal are both built on two entirely distinct plans, and with entirely different materials. One style of house is single-storied, erected by driving roughly-shaped tree trunks or wooden posts into the ground, filling in the interspaces with split-bamboo mats, and throwing a highly-pitched thatch roof on to bamboo rafters; the whole of the latter being held in position by means of ropes and thongs attached to the main posts. These bamboo grass houses are well calculated to stand the stresses due to an earthquake shock on account of their ready pliability. The other kind of house, though differing architecturally according as it is of native or European design, agrees in having brick walls, frequently raised to two, and sometimes to three, stor covered with plaster or stucco, and usually bearing a

heavy solid flat roof of brick and cement surrounded by a parapet. These houses have all been badly rent, sometimes beyond repair, or even ruined. There is also occasionally a kind of house which partakes of both the above described styles, having brick walls and a thatch roof, and there are, in addition, many huts of dry mud and thatch belonging to the poorer natives. Both these kinds have suffered very much, for the former, whilst possessing all the defects of unpliable walls, has none of the advantages of a strong flat roof to tie them together, and the latter of course readily cracks and crumbles on account of its material lacking coherency.

Most of the Europeans at Serajganj, which is a very small station, had left their solid-built dwellings, and were living in bamboo houses and offices. The former were too much split to allow of remaining in them with safety, especially as repetitions of small shocks daily indicated that the disturbing forces at work below were not yet in a state of complete equilibrium. I shall return to the house cracks later on, at present dealing only with the chimneys.

The two chimneys of the jute works (see figure 1, which is reduced from the original plans, kindly lent me by Mr. Allister Macdonell, the owner of the mill), were both broken by the earthquake. The heights of the mill and factory chimneys were 135 feet and 95 feet respectively; and 40 feet from the summit of the larger and 11 feet from the smaller were shot away.

Mr. Robertson's account.

Mr. Robertson, the manager, was fortunately an eye-witness from a position between the chimneys at the time of the earthquake, and he asserts that there seemed to be a sudden thrust from below, by which the upper part of the south chimney was first shattered, and jerked off; and for some time a shower of bricks and mortar continued to fall all round the base. A moment after the large chimney had gone, the factory chimney to the north was affected in exactly the same way; its upper part being jerked off into the air, and a shower of bricks subsequently descending from the broken edges. If these impressions are to be relied on, two points of importance come out, (1) that the earthquake wave with a steep angle of emergence shot away the upper parts of the chimneys by its first and second semiphases combined, but was unable to overturn them as wholes, because of their flexibility, which would considerably relieve the strain, and because of their breaking above, which would further ease them; and (2) if the south chimney was the first to fall—and there seems no reason why a very slight difference in the order of breaking should not have been appreciable by the eye—then it is clear that the shock must have come from some point generally speaking towards the south: it is in fact easy to demonstrate that the difference in time of the arrivals of the shock at the two chimneys would have been appreciable. For the chimneys are 338 feet apart, lying very nearly north and south: now Mallet gives 825 feet per second as the rate at which a wave of elastic compression travels through sand, and though the soil at Serajgunj is clay and sand combined, it would certainly not be a much higher rate than this. Hence about $\frac{3}{7}$ths of a second would have been consumed in travelling between the chimneys, a period of time well above what can be detected by the eye. In reality, however, some small reduction on this value must be made on account of the probable direction of the shock being something east or west of south, a condition which

would have diminished the time occupied by the wave in travelling between the chimneys.

I now come to my own observations of the ruins. The large chimney, the only one which had been in use for some time, I found had been hastily repaired by knocking away the loose bricks at the top and putting on a temporary coping. The old factory chimney had been left untouched while this work was going on, and I could examine everything in the state just as it was immediately after the earthquake. The broken surface I found was exceedingly jagged and irregular, with its highest part towards the north-west, a feature agreeing in every way with the statement of Mr. Robertson, that the edges, during the secondary vibrations, crumbled away, and not by any means presenting the appearance of a clean cut fracture. From photographs of the large chimney, I was able to see that its original state before the repairs was very much the same as that of the small chimney. On the other hand, at about middle height of the chimney, there was a very distinct crack, showing on the east-north-east and north-north-east faces of the factory chimney which is an octagon in section. The crack was such that, roughly speaking, it might have been made by a plane of fissuring, which for convenience, and in conformity with geological nomenclature, we may speak of as "dipping" towards the north-west. The same was observable in the mill chimney. The angle of dip would be steep, perhaps 60°, but owing to the great height of the chimneys, a reliable observation could not be made. An examination of the debris around the base of the factory chimney brought out many points of interest, and corroborated the account of Mr. Robertson. I found the ground so covered was elliptical in shape (see fig. 2), with its long axis running north-40°-west and south-40°-east; but whilst in the former direction the fragments extended 29 feet from the base, in the latter they only extended 25 feet, showing that the mass of the material had gone over towards the north-west. And besides, there was a very conspicuous difference in the nature of the fragments on either side. Towards the north-west, the broken parts of the chimney were to some extent coherent in themselves, being made up of groups of 20, 30, or 40 bricks still showing traces of the shape of the walls; but in the opposite direction nothing but individual bricks, and fragments of bricks could be found. Again, towards the north-west, some 2 or 3 feet from the outermost edge of the debris, we came upon the broken remains of the iron coping. Thus we have very clear evidence from the ruins, that the mass of the broken part of the chimney, together with the iron coping, fell in the direction north-40°-west, whilst only bricks and mortar, loose or broken, fell towards the south-40°-east. The mill chimney, though not so adapted for observations on account of the debris having been cleared away, nevertheless gave some information from the circumstance that in falling, the broken part had crashed through the workshop roof and parapet. As in the preceding case the area of the debris, or marks of the debris, was elliptical, but with the long axis running in this case nearer north-north-west and south-south-east, though these directions were not got so satisfactorily as in the case of the factory chimney. Here, too, the broken roof showed that the fall had been much greater towards the north-north-west; for up to a distance of 32 feet from the chimney the roof

My own observations.

was broken-in in that direction, whilst in the opposite one the bricks were only scattered on the ground 17 feet from the base of the chimney. The iron coping in like manner was found towards the north-north-west, in a position pointed out to me by the manager, where it had penetrated through the roof into the workshop.

Deduction.

Now putting these colligated facts together with the statement of Mr. Robertson, we may from them draw the safe conclusion that the shock came from the direction south-east or south-south-east, and shot the bulk of the broken part of the chimneys over towards the north-west or north-north-west.

Temples at Sherpur. (Bogra district.)

The cracked condition of these form the next piece of evidence which I place among those of first importance. They are small Hindu shrines to the god Siva, octagonal in shape, the height being usually two or three times the diameter; and either entirely isolated, as the one shown in fig. 3, or with sometimes a porch on one side. In every way they were good subjects for observing the direction of the cracks, for their solidity and symmetry prevented the fissures from being influenced by any pre-disposing lines of weakness. The diagram, fig. 3, shows the general appearance of a couple of cracks in one of these temples. They were exceedingly well-cut fissures, and discernible at a good distance. The dip of the fissuring plane was 45° north-west. In two more examples of temples of the same build and size, except that a porch was attached to one, I found fissure planes respectively dipping west-north-west at 55° and 60°. Attaching a little more value to the evidence of the first temple, inasmuch as it was more decidedly rent than the others, we may take as relative means north-50°-west for the direction, and 50° for the angle. From these we get south-50°-east as the direction from which the earthquake shock came, and 40° as the angle of emergence at that place. Besides the temples, there were some good examples of house corners shot away, generally in a north-west direction, the fissure plane making an angle of 55° with the horizon in some places; but as a rule among the 100 destroyed houses at Sherpur, the collapse was so complete, owing in a great measure to the buildings being old, that neither directions nor angles could be obtained. Since Sherpur lies to the north-west of Serajganj, we may take it that the observations there corroborate the truth of the conclusions drawn from the jute works' chimneys, whilst in addition we get a rough estimate of the angle of emergence for the alluvial soil of Sherpur; though this, it must be remembered, will probably be steeper than the real angle owing to refraction in passing from the highly elastic solid rock to a clay stratum of very low elasticity.

Tomb, Jamalpur.

Hearing, when at Maimensing, that a tomb had fallen in the Jamalpur cemetery, a report considerably qualified by the fact that an order had been issued for it to be cleared away, I hastened to that place, and fortunately arrived before the order had been carried out. It was a small cemetery, containing some ordinary graves, and this one large tomb, erected in 1837 to Anne, the wife of Major Cox of the 58th N.I. The erection consisted of the tomb proper, a rectangular raised sarcophagus, surrounded by eight pillars in a circle, and covered by a hemispheroidal dome, or canopy. The whole was built of brick and stucco, and represents a common form of tomb

in Eastern Bengal cemeteries (see fig. 5). The appearance, when I saw it, was as shown in fig. 6; the pillars had all fallen in one direction, and split up into various lengths; whilst the great heavy canopy had fallen towards the south-10°-east, and coming into violent collision with the low wall of the cemetery, had split into several pieces, some of which fell into the road beyond, and the rest lay, partly on the foundation base, and partly on the ground between it and the wall. The tomb itself was uninjured, except at the upper corners, doubtless by the canopy just grazing it as it fell. A glance at the elevation, and the overthrown state, will at once illustrate the manner of its fall. The weight of the massive canopy, and the slenderness of the pillars, make it clear that the inertia of the upper part of the mass was sufficient at the time of the earthquake to prevent it moving along with the pillars, and consequently the tomb fell in the direction *from which the shock came.*

The following are the dimensions of the parts and adjuncts of the tomb, gathered from the ruins themselves:—

Base, 12 feet 10 inches square; 9 inches thick. One side faces north-3°-east.

Tomb proper, length from east to west 4 feet 4½ inches; breadth 3 feet 4½ inches; height from base 6 feet.

Pillars (8), 6 feet 10 inches high; 1 foot 8 inches in diameter.

Stone capital on each pillar, 2 inches thick.

Circle of pillars, diameter of outer edge 11 feet 4 inches, equal to diameter of canopy.

Height of hemispheroidal canopy 5 feet 8 inches; thickness 1 foot 7 inches.

I shall discuss the figures later on in their bearings on the velocity of the wave particle, together with the data afforded by the chimneys at Serajganj, at present merely drawing attention to the fact that the line of the shock, north-10°-west and south-10°-east, when laid down on the map, is seen to cut the line from Serajganj at a point between Dhamra and Atia, on the south-west side of the Madhapur jungle. This gives us approximately the position of the seismic vertical.

Gateway arches, Muktigarchia.

This example is put with those of first importance, because the nature of the construction was such as to favour overthrow by reason of its inertia; and notwithstanding the fact that the conclusions which may be drawn from it contradict, in some degree, those previously arrived at. The arch is a brick and stucco arrangement, and, as will be seen from the diagram (fig. 7), very problematical in its uses, since it supports nothing whatever. There is a duplicate one some 30 or 40 yards away, and both open into a garden belonging to a local zemindar. As both have been affected similarly a description of one will be sufficient. The gateway faces south-13°-east, and when I saw it the arch had been cut clean off on a level with the top of the gate-spikes. The fragments were piled in a heap on one side, but from the freshly patched indents on the cement pathway, and from the broken spikes, it was evident that the falling arch was not displaced horizontally to any great extent in a direction at right angles to the gate; but that, probably snapping into two or more fragments, it dropped nearly vertically down on to the gate spikes, but with sufficient leaning towards the south side to turn all the fragments in that direction. The indents however were not situated midway between the gate posts, but more towards the east than west, showing that the shock was not

orthogonal to the plane of the arch. From the gate facing south-13°-east, and the obliquity of projection of the fragments, we must look for the destroying force in a south-east direction. But Muktigarchia stands nearly north-north-east of the seismic vertical already obtained on the best evidence; and the only way for the apparent contradiction to be reconciled is either by the assumption of another minor centre of disturbance south-east of Muktigarchia, or of a reflected wave.

Temple, Maimensing.

This was one of a kind similar to those mentioned at Sherpur, but slightly more lofty, *i.e.*, a Hindu shrine to Siva, octagonal in form and with a conical apex. A fine, but perfectly distinct crack, was discovered cleaving through the lower story. Viewed from the inside where it was seen better, the highest point of the crack was seen to be at the south-south-west angle. Hence the fissuring plane would dip towards the north-north-east. The angle was low, about 35°. This gives a direction for the shock south-south-west, and a very high angle of emergence. The direction, when laid down on the map, is seen to cut the point already obtained as the seismic vertical. It should be mentioned, however, that a heavy brass water-vessel, threaded on an iron rod, which forms an ornament for the summit of the conical roof, was bent over towards the south-east at an angle of about 60° with the horizon. It was prevented from falling by a heavy chain attached to it, and which hung down from the roof in the interior of the temple. I was unable to learn whether the ornament was free to turn on its base, as on a pivot, or not, and so the value of the direction here indicated is lessened by the doubt that it might have had a rotatory motion given to it, and eventually have settled into its present position quite irrespective of the direction of the shock.

This brings to a conclusion my examples of the first order of importance. Those of secondary importance, and some few exceptional phenomena, will be now described.

(*II*).—*Examples of secondary importance.*

Wall cracks, Serajganj Jute Works.

The mill being a rectangular building, with one wall facing externally towards the south-68°-east, it will readily be seen that the direction of the earthquake shock, as obtained from the chimneys, was very nearly diagonal with regard to the four main walls of the building. It is probably due to this circumstance, and to the fact that iron tie-rods are used throughout to bind the walls together, that comparatively little damage has been done; though it should not be overlooked that a mill, with the jar of machinery constantly throwing every wall into a state of tremor, would be much more likely to stand an earthquake tremor than any other building that was, so to speak, not so accustomed to vibrations of its parts. Such damage as has been done is just in the position we should expect. From the circumstance that the shock was diagonal to the main walls, we may imagine it resolved into two equal component shocks, each at right-angles to one set of parallel walls, and each doing about the same amount of damage. But whereas the east-south-east and south-south-west walls[1] are those which would tend to be driven inwards by the shock, and would be supported by the neighbouring walls to a large extent, the north-north-east and west-north-west walls being respectively driven outwards by the shock, and having no walls in

[1] *N.B.*—East-south-east wall means a wall facing east-south-east.

that direction to support them, it is more than probable that they would be the ones to crack. An examination of the building shows that this has been the case. The north-north-east wall, between the mill and the factory, but quite unconnected with the latter, and so unsupported by it, has a line of crack near its junction with the roof running the whole length of the building; whilst on the west-north west side of the mill, the wall between it and the 'softening-room' is also cracked for about half its length. Another parallel wall, east-south-east of the 'baling-house,' in connection with the mill, has similarly started a crack, which, dipping at an angle of 50°, penetrates the line of arches running down the centre of the said room, and this is crossed by another, parallel in strike, but dipping at right angles to it.

Mr. Macdonell's house, Serajganj.

I take this as another example of wall cracks, partly because it is the largest house in the station, and has been the most decisively cracked; and partly because, unlike the mill, it lay with its walls fronting, or at right-angles to the direction of the shock, and well exemplifies, both in the direction and magnitude of the cracks, how much more severely a house thus lying is shattered, than one lying diagonal to the shock. There is no impediment in this case to the house freely rocking to the shock, but the momentum thus accumulated becomes fraught with great danger on account of the unpliability (practically speaking) of the walls in such structures. The house is a double-storied one, in the Calcutta style, with a lower and upper verandah facing south-52°-east. As in all cases of double-storied houses, the upper part has been the most damaged; for such rents as go completely through the house from top to bottom, are wider above than below, and there are many others which only penetrate through the upper story, and then die away. The main cracks are best seen in plan on the flat roof for this very reason; and I may here state that every house which I subsequently saw of this type, and which lay at right-angles to the shock, or very nearly so, has four types of cracks as seen on the roof. There is first of all the verandah crack, dividing the verandah from the house, and usually the worst, inasmuch as it takes its origin along a very conspicuous line of weakness. On the opposite side there is usually the portico crack, in a similar way starting along a line of weakness. Thirdly, there is the main crack, near the centre of the house (see diagram, fig. 8), usually the most reliable, cutting like a knife through parapet, pillar and roof, and rending the house from top to bottom. Lastly, there are some few corner cracks at right-angles to this. Such are the cracks in Mr. Macdonell's house. When their projections are traced on the vertical side-walls, all but the verandah crack are seen to dip about 60° north-52°-west in their upper parts, but lower down they usually wander more irregularly along windows and doorways, finally branching in various directions at a very low level where the momentum of the moving walls would have been less.

A tower, about 24 feet high, built above the stables, was also cracked in the same direction, the angle being about 55°.

Joint Magistrate's house.

Of other houses in the station, mention may be made of the Joint Magistrate's, which lay even more in the direct line of the shock than the previous one, the verandah facing south-40°-east. It was a single-storied house with brick and plaster walls, but with a thatch roof. It had accordingly suffered very severely, the main crack and verandah crack dipping north-40°-west with an angle of about 70.°

A single-storied house with flat solid roof and solid walls showed as many as three main cracks, and a verandah crack in plan on the roof, and several minor ones. The house was north and south; and the cracks dipped slightly west of north. They were vertically inclined near the verandah, but in the other direction gradually assumed an angle of 60 or 70.°

Mr. Mollison's house.

Several native gentlemen's houses were also shattered, but with one exception gave no fresh data. This exception, which is rather an old house, is double-storied, and faces south-13°-west. The shock came diagonally upon it, and shot away one corner by a plane of fissuring, dipping north-32°-west in an irregular manner.

Other houses.

At Subornkholi and Muktigarchia, though some houses were cracked, and a small chimney stalk rent near the summit, there was nothing which afforded safe evidence. In like manner an inspection of the Rajah's palace at Muktigarchia, which has suffered terribly by the earthquake, on account of its peculiar construction, was equally barren in results.

At Maimensing there were some better results. The jail has its enclosure wall facing north-north-east cracked for a long distance near the bottom; and at the corner where it joins the east-south-east wall it has parted from it outwards, leaving a gap of an inch or so wide. The south-south-west wall near the entrance gates is also cracked more or less horizontally for some distance. But neither of the two walls at right-angles to these have been cracked, save one for a short distance. This is what should happen with the shock coming from the south-south-west, the direction of the seismic vertical. Many of the buildings within the enclosure are nearly new, and such cracks as they show would favour a shock from either of the opposite directions. One older building, however, has a crack at its north-north-east end of very serious size, dipping nearly vertically. This better agrees with the evidence of the enclosure walls.

Maimensing jail.

The dispensary on its south-east and north-west end walls showed a set of intricate fissures, crossing one another at right-angles, and such as could have been produced by a fissuring plane dipping either north-east or south-west at 45.° Those in the former direction were the most conspicuous, inasmuch as they started originally from the summit or sides of the walls, whilst the others started from some point on them.

Dispensary.

A mosque (see fig. 9), near the dispensary, is interesting because it has had its north-north-east corner walls shot away, evidently by a shock coming from the south-south-west, which has also rent the north wall in three places, and one of the domes. There is also an approximately horizontal crack in the west wall at about half its height.

Mosque.

A house belonging to the Rajah Saruja Kantu Acharji was fortunately placed, and received the full effects of the shock. It was rectangular, and lay with its ends facing east-south-east and west-north-west, very nearly. These end walls were also fortunate in not being too much pierced by windows and doorways. They revealed cracks produced by planes of fissure dipping north-north-east 50° and south-south-west 40° which crossed one another at right-angles. If anything, the planes dipping south-south-

House.

west were slightly the more pronounced, of the two. This house, and the dispensary already mentioned, were both good examples of the effects of an earthquake wave rising upon a building exactly at right-angles to its path.

The new Kachahri.

This is the only other building which left any legible record. It is in an unfinished state of building, but beyond some few small cracks no permanent injury has been done. There seems no doubt that this leniency is mainly to be put down to the newness of the mortar, and the consequent pliancy of the walls. The cornice running along the top of the walls has however fallen at several points, because it needed the binding effects of a roof to keep it in place. The fall has only taken place from such walls as faced north-22°-west, or south-22°-east, and slightly round corners on the east-north-east walls. The largest piece has gone from the north-north-east corner. As the building lies with its long axis east-north-east and west-south-west, no doubt there would be more tendency in the walls to rock at right angles to that line than with it; but, as the shock came diagonal to the building, some small resolved part of it must be allowed to set the end walls in a tremor, though not so violently on account of their relative shortness. The results show that the more conspicuous shaking *was* imparted to the long walls facing north-north-west and south-south-east, and a smaller shaking to the shorter ones at right angles to these; whilst the far larger piece of the cornice tumbled from the north-north-east corner shows that that was the point the least supported, as would be the case with the shock from the assigned south-south-west direction. It may also be noted that the small cracks in the arches of the lower story are also at this corner of the building.

Dacca.

At Dacca I got very little evidence of the earthquake, though from all accounts the shaking here was very severe. The police reported a temple fallen at Barisur on the opposite side of the river, but on visiting the place I found only the blackened ruins of one which had collapsed from decay some years ago. Fig. 10 represents a house on the river bank that has had the stucco mouldings shot away on its south side and south-east corner. The south-west corner also showed two cracks dipping south-east roughly.

Several other houses also showed the same thing, both cornices and plaster falling towards the south or south-east, and never towards the north. A careful scrutiny in the cemetery was unrewarded by any fall greater than bits of brick and plaster, and an earthenware vessel from the summit of a tomb. The vessel, originally threaded on an iron spike, had broken, and only half of it fallen to the ground, and was, in consequence, of doubtful value as evidence. It fell towards the south-south-east, which was also the general direction of the plaster chips. Thus there was just sufficient evidence here to bear out all previous conclusions with regard to the position of the seismic vertical, but nothing to corroborate it. On the whole, the damage done in Dacca is disproportionately small compared with other places equally near the centre of disturbance. The reason for this I shall consider later on.

(*III*).—*Exceptional phenomena.*

Earth fissures.

Earth fissures opened at Serajganj, Subornkholi, and Jamalpur, and some few other places. In every case that I examined they had taken place either by the banks of a river, or elevated road

way, or the sloping sides of a tank. In one case at Subornkholi, near Mr. Webster's jute mills there were some irregular cracks, opened apparently on the flat, though not many yards from some water. They were fringed all round the margins by fine sand, which bore testimony to the statement made by Mr. Webster that water oozed up through these cracks carrying the sand with it, and sometimes even spurted up into the air some few feet. When at Jamalpur, I received from the Deputy Magistrate some pieces of lignite which had been similarly thrown up through fissures along with sand and water at Sherpur (Maimensing district). There is no reason to imagine that these fissures differ in origin from those so well described and explained by Mr. R. D. Oldham, in his discussion of the Cachar earthquake of 1869, published in Vol. XIX of the Memoirs of the Geological Survey of India, and to which I refer the reader. It is there shown that during the passage of an earth wave, contiguous vertical zones are moving respectively forwards and backwards at the same moment, but that on level ground the cohesion and inertia of the motionless masses of clay in front and behind are sufficient to prevent rupture. On the other hand, when a bank is approached, the particles of clay moving forward have no inert clay mass in front to stop them and take on their motion, and consequently those particles break away from the zone of backward driving particles and a fissure is formed.

Wells.

In three cases wells were curiously affected by reason of the same causes. At Serajganj a well pipe, 13 feet 7 inches long and $1\frac{1}{2}$ inches in bore, was filled throughout with sand tightly jammed into it. I was told that, at the time of the earthquake, water rose in the well, and that since then the bottom of the well had broken through into the underground vacancy made by the ejection of the sand. At Subornkholi I saw a well which had had its tiled casing, about $1\frac{1}{2}$ feet in diameter, moved towards the north-west, so that, looking down through the brick mouth of the well, it was seen to be entirely on one side instead of in the centre. I also heard of another well in the neighbourhood out of which a brass vessel had been hurled some distance.

Tank, Serajganj.

The water of a tank close by the jute company's works, Serajganj, was thus affected, according to an account of the manager. The long axis of the tank lay north-20°-east, and the water seemed to run east and west from the sides, gathering up in the centre, and then to spread out again to the sides.

Brick stacks.

Some brick stacks in a brick yard at Maimensing were partially overthrown. They all stood 3 feet 9 inches in height; and the north-north-east corners were the ones shot way. The outermost bricks fell at a distance 4 feet 9 inches from the outer edge of the stack, a distance obtained by taking the mean of eight different measurements.

(IV).—Discussion of data.

Seismic vertical and depth of focus.

If we take a mean of the directions of the fallen chimneys at Serajganj, also the direction of the tomb at Jamalpur, and that drawn from the cracks at Maimensing, we have to place the seismic vertical as emerging on an area $3\frac{1}{2}$ miles in diameter with its centre 37 miles south-37°-east (true) from Serajganj, or 90° 6′ 30″ East Long., and 23° 59′ 20″ North Lat. But there is still another method of

procedure open to us. If we take some three towns on the map where the destruction to buildings is markedly greater than elsewhere, and describe a circle through them, the centre of that circle will be the position of the seismic vertical. Now there is no doubt that Sherpur (Maimensing district), Bogra and Nattore are three such places, as reference to the telegrams and letters published in the *Englishman* between the 15th and 25th July will show. These three places are all about equidistant from the assigned position of the seismic vertical near Atia, and thus the position of this point is made doubly certain. In discussing the depth of the focus we have also a double method, the first method being to take the angles of emergence as deduced from the fissures, and apply the formula—

$$D = C \tan E,$$

where D = depth of focus, C = distance from seismic vertical, and E = angle of emergence.

At Sherpur (Bogra district), C = 61 miles, and E = 40°,

$$\therefore D = 61 \times \tan 40°,$$

that is, D = 51·18510 miles, or about 51 miles.

At Maimensing we had 40° and 45° as the angles of emergence, taken from the cracks in the Dispensary, and one of the houses belonging to the Rajah. Now, taking $42\frac{1}{2}°$ as the mean angle, since Maimensing is 55 miles from the seismic vertical we have—

$$D = 55 \times \tan 42\tfrac{1}{2}°,$$

that is, D = 50·39815 miles, or about 50 miles.

In the second method, the depth equals the diagonal of the square described on a radius of the circle passing through three or more points where the destruction to buildings is greatest. So that, taking the radius of the circle described about the towns Nattore, Bogra, and Sherpur (Maimensing district) as 74 miles, we have—

$$D = \sqrt{2 \times 74^2}, = 104 \text{ miles nearly.}$$

The second method thus gives a far greater depth for the focus than the first. But both are far higher values than are usually assigned to an earthquake focus. This may be partly accounted for by the fact that, in its passage from the lower solid strata into the upper alluvial soil of Bengal, the earthquake wave must have been refracted; and so the emergence angle would appear too steep.

On the whole, owing to reasons which will be given below, when treating of the arc of violence, we may place more reliance on the former than on the latter method in this particular case. So, if we take the mean depth of the two first calculations, and subtract ten per cent. for refraction (an arbitrary amount), we have about 45 miles as the depth of the centre of disturbance.

The arc of violence.

In considering those points on the earth's surface where the greatest damage has been done to buildings, which points, as before mentioned, can be included in a circle with the seismic vertical for centre, we are at once struck by the fact that it is not at every point alike of this circle that great disturbance has occurred, but only at certain of them forming an arc of about 90° having Maimensing at one extremity and Nattore at the other. This arc of violence is indeed wonderfully contrasted with the rest of the circle;

for if we take into consideration a large station like Dacca, which is not quite so far from the seismic vertical as Serajganj, we find the destruction caused there in no way comparable to that at that place. At Pubna also no very great damage has been done, whilst from Faridpur and Kumila (Comillah) there have been absolutely no reports nor telegrams in the newspapers. To understand the reason for this a geological map must be consulted: it will then be seen that, whilst places on the southern arc of the circle of greatest possible destructibility have no outcrop of metamorphic rock nearer than 200 or 300 miles, all those places situated on the actual arc of violence are within 75 miles of solid rock, namely, the metamorphics of the Garo hills, or the Rajmahal trap; some places being even as little as 37 miles from the Garo hills. In other words the great plain of Bengal, though 325 miles broad between Chittagong and Balasore, narrows in a northerly direction between Rajmahal and the Garo hills to 135 miles. Now from the fact that the latter places are where the two masses of metamorphic rocks of Chota Nagpur and Assam respectively most nearly approach one another, we may infer that a line joining them would cross that part in Bengal where the depth of alluvial soil is less, and where the metamorphics come more nearly to the surface than at any place further south. We thus see that the arc of violence is situated near where this shallowing of the alluvial soil takes place; and we at once recognise that the latter is the cause of the former.

In support of this, and also, the better to enlarge on my meaning, I will take the liberty of quoting from Mr. Mallet's report on "Earthquake phenomena" in the Report of the British Association for 1850, when speaking of the great Calabrian earthquake. He says:—

"The centre of effort in this earthquake was under the great plain, and probably about under where once stood the village of Oppido, but at an unknown depth. The observations made amount to no more than this; that the shocks did less mischief to structures on the granite or slate rocks of the hills, than they did to those on the plain of clay, &c.; that the destructive effects of the shocks were very great along the line of, junction of these, at the bases of the hills (from which some philosophers of that time concluded that the earthquake came from the mountains), and that along this line, shocks in close succession were felt, not only horizontally and vertically, but also in opposite directions.

"Now we may *a priori* account for these facts, on the principle that the velocity of the shock or earth wave depending on the density and modulus of elasticity of the formation through which it passes, and its velocity being greatest in those whose elasticity is highest, while its range of motion is most limited in the same; therefore the shock here was of less velocity in the plain than in the rocky hills; but had in the former a longer range of oscillation, and hence did most mischief in the plain. Along the line or plane of junction of two formations of different elasticities, &c., the earth wave will change its course and also its velocity (like light in passing from one medium to another), and here the wave will be divided, part of it will be refracted. and part reflected (or total reflections may take place if the angle of incidence be suitable to the plane of junction); and the latter portion of the wave will in such case double back upon itself, and give rise to a shock in the opposite direction to the first one. Hence, along such a line of junction, the destructive effects will be very great."

The case we are considering, though not quite agreeing with the one quoted, differs only in degree; such difference as there is depending on the fact that the centre in our case was too far away from the hills for the circle of greatest destructibility to cut at any point the line of junction between the metamorphic hills and the plains of clay. Still, the fact that the destruction is accentuated along

the arc of violence, *i.e.*, the arc nearest the hills, shows that reflected waves from the quickly transmitting rocky basin must have started out back from the hills before the slowly travelling wave in the clay reached them; and those reflected waves, though not strong enough of themselves to produce destruction on the actual line of junction of the plains and hills, must have had some considerable power in augmenting the effects of the direct waves when the two sets met, and even for some time before and after meeting, since many objects caught still vibrating from either shock would be more easily overturned by the succeeding one.

And once more, the smaller depths of alluvial soil along the northern arc of the circle of greatest destructibility would receive the full effects from the direct shock, whilst the thicker pad of clay on the southern arc would, by being violently moved as to its particles in its lower part, have in some measure dissipated the motion before it arrived at the surface.

We thus see that primarily it is owing to the shallowing of the deltaic deposit of the Ganges and Brahmaputra, as the metamorphic hills or their sub-alluvial representatives are approached, and also to the proximity of the two latter, that more destruction has been caused north of the seismic vertical than south of it.

We may also expect that owing to the same causes the circle of greatest destructibility to buildings, as laid down on the map from the arc of violence, is of much larger diameter than it would have been in a perfectly homogeneous country; and therefore estimations of the depth of the focus from the diagonal of the square of the radius of that circle will have far too great a value; as we were led to expect by their non-agreement with the angle of emergence method.

Velocity of the wave particle.

This can be obtained within limits from the tomb at Jamalpur and the chimneys at Serajganj, the dimensions of which have already been given.

In the first case we have to treat the fallen body as one upset in the direction from which the shock came by its inertia of rest, during the first semiphase; and in the second case we have an example of oscillation of a body beyond its limits of flexibility, due to its inertia of motion during the second semiphase.

Overthrow of the tomb canopy.

Let us first take the simpler case of the tomb at Jamalpur. If we call 8 W. the weight of the canopy, then, since it is supported by eight pillars, each of them bears a weight equal to W, that is $\frac{1}{8}$th of the whole. Now since the whole canopy is symmetrical about any vertical plane passing through the centre, we may look on the mass of the canopy as also divided into eight parts and individually placed vertically above each pillar, at the same level as the centre of gravity of the whole, that is, 2 feet 2 inches above the pillars. For, if we take any pair of pillars opposite one another, we see that, just as much as the one is helped in its upsetting by the mass of the canopy being on one side of it, the other in like manner is hindered to the same extent, and since they are in rigid connection by the canopy the one condition balances the other. Thus the problem narrows itself to the overthrow of one column supporting a mass proportional to W at a point $2\frac{1}{6}$ feet above its upper end.

It is now necessary to ascertain the proportional weights of the column and the supported mass. We obtain this by calculating their respective volumes, since

the material being the same, the weights will be proportional to the volume. The whole of the canopy contains 412,142 cubic inches, and therefore $\frac{1}{8}$th contains 51,518 cubic inches. Each pillar contains 26,389 cubic inches, and will therefore be about half the weight of the portion of the canopy it supports; and since the mass of anything is proportional to its weight at the same point on the earth's surface, we have the mass of the portion of the dome supposed concentrated above the pillar equal to twice the mass of the pillar itself.

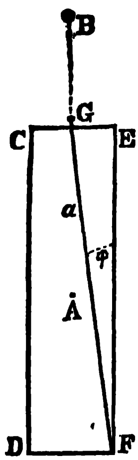
We must now get the moment of inertia of the whole in order to find the centre and radius of gyration. For since the whole may be considered as a compound pendulum swinging on one edge of the base of the pillar, we need to find the length of the simple pendulum which gyrates in the same time, *i.e.*, the distance of the position of the centre of gyration (where we may consider the whole mass of the pillar and its burden concentrated) from the axis of gyration. By dividing the system of pillar and its portion of the canopy into suitable portions, and taking the sum of the products of their masses into the squares of their distances from the axis of revolution, we obtain—

$$m\left(\frac{2557}{12}\right) = \text{the moment of inertia of the whole system,}$$

where m = the mass of the pillar, and therefore 3m = the mass of the system.

$$\text{then } r^2 = \frac{m\left(\frac{2557}{12}\right)}{3m} = 71\tfrac{1}{8} = (\text{radius of gyration})^2,$$

that is to say, the position where we may suppose the whole mass of the pendulum concentrated into a single heavy bob is distant $\sqrt{71\frac{1}{8}}$ feet from the axis of revolution.



In the annexed figure let CDEF = the pillar of which A is the centre of gravity, and let B = the point where the mass of $\frac{1}{8}$th of the canopy is supposed aggregated. Then dividing BA into three equal parts, of which BG is one, gives us G the centre of gravity of the whole system, since the masses at B and A are proportional to 2 and 1. The point G is 2 inches above CE or 7 feet 2 inches above the base DF. Join GF and let the angle GFE = ϕ. Then since DF = 1 foot 8 inches and EF 7 feet, we can get the length of GF = $7\frac{5}{24}$ feet.

Now in order to upset the system we must cause G to revolve about the axis F through the angle ϕ, and the measure of the velocity of the horizontal force acting at G competent to raise it to the height entailed by going through that angle is the measure of the velocity of the horizontal component of the earth wave that is at least necessary to overthrow the system.

Let a denote the distance in feet of the centre of gravity of the system from the point F, then the statical work done in upsetting the body whose weight is W^1 is—[1]

$$W^1 a\,(1 - \cos.\,\phi$$

[1] See Mallet. Neapolitan Earthquake of 1857, p. 125, Vol. I.

This must equal the dynamical work acquired which is equal to the work stored up in the centre of gyration or

$$W^1 a\,(1-\cos.\,\phi) = \frac{W^1\,\omega^2\,r^2}{2g.}$$

where ω is the angular velocity of the body at starting, r the radius of gyration, and g the velocity acquired by a falling body in one second of time.

Equating these two values of the work done we find

$$\omega^2\,r^2 = 2ga\,(1-\cos.\,\phi).$$

But ω the angular velocity = the statical couple applied divided by the moment of inertia or

$$\omega = \frac{V\,a\cos.\,\phi.}{r^2}$$

Squaring and substituting

$$V^2 = 2g\,.\frac{r^2}{a}.\,\frac{1-\cos.\,\phi}{\cos.^2\,\phi}$$

Now putting the actual values for these letters we have

$$V^2 = 64 \times \frac{71\frac{1}{6}}{7\frac{5}{24}} \times \left(1-\frac{7\frac{1}{6}}{7\frac{5}{24}}\right) \div \left(\frac{7\frac{1}{6}}{7\frac{5}{24}}\right)^2$$

therefore $V^2 = 4$ nearly,

or $V = 2$ feet per second, the velocity of the horizontal component of the earthwave. Then, since the angle of emergence here was 39°, we have

$$V^1 = \frac{V}{\cos.\,39^\circ} = 2{\cdot}56 \text{ feet per second.}$$

V^1 here represents the least value necessary to overthrow the canopy, and, so far, the actual velocity might have been anything above 2·56 feet per second.

Tomb itself.

But, from the fact that the body of the tomb itself was not overturned, nor even fractured at the base, we know that the velocity was less than would have been required for that purpose; and so we can limit the velocity in two directions, though not within very narrow limits.

The following is the formula for the fracturing of a solid parallelopiped at its base by a subnormal wave:—

$$V = \frac{2}{3}g \times \frac{L\beta}{a^2} \times \frac{\cos.\phi}{\cos.\,(\phi+e)}$$

where g as before = 32 feet per second

ϕ = 25°

e = 39° the angle of emergence

a = 6 feet, the height of the tomb

β = $3\frac{1}{3}$ feet, width of the tomb

L = 4 the modulus of dynamic adhesion between the bricks and mortar.

$$\therefore\quad V = \frac{2\times 32 \times 4\times 10}{3\times 3 \times 36} \times \frac{{\cdot}90}{{\cdot}43}$$

$$V = 23{\cdot}22 \text{ feet per second,}$$

or the velocity necessary to fracture the tomb from its base. Now as this has not occurred, the velocity must, at greatest, be not so high as this value.

Projection of canopy.

But again, we have in the case of the canopy, not merely a body upset, but also one projected some distance.

For the centre of gravity of the whole system had travelled horizontally 11·50 feet from the position vertically beneath where it was when the structure was just on the verge of falling. Now, if the canopy had been gently lowered over on its side, so that no centrifugal force generated was sufficient to overcome the pressure due to gravity, it would have lain with its centre of gravity 3·50 feet short of this, or the distance from the point of revolution would have been equal to the height of the centre of gravity, plus half the diameter of a pillar, that is, 7 feet 2 inches and 10 inches. This $3\frac{1}{2}$ feet extra throw must have been due either to one cause alone, or to two combined. It must either have been caused by the centrifugal force of the body revolving under the influence of gravity alone, or by the combined effects of it and the projecting force of the earthquake. If it had been due entirely to the first of these causes, we should have had the system springing away from the centre of revolution when the cosine of the angle through which it had turned was $\frac{2}{3}$, and not before. Now it is easy to see by noting the proportions of the parts shown in the elevation fig. 5, Pl. II, and joining the necessary angles, that if the body had not left its point of revolution at an earlier period, the north edge of the canopy would have struck the upper part of the tomb over half its surface, causing a collision which would have left undoubted traces. But it has not done so, or rather the south edge of the tomb has only just been grazed as represented in the figure. Consequently there must have been some other force in addition to that of gravity acting on the body, and so helping the centrifugal force due to gravity to project the body at an earlier moment. Also, since the upper surface of the tomb is 1 foot only below the canopy (when the latter is on the verge of falling), it must have been shot away before that vertical distance had been descended, though not much before, inasmuch as the canopy did just graze the tomb. We shall not be far wrong if we take it that the pressure on the ground was overcome by centrifugal force at the moment when the canopy had descended $\frac{3}{4}$ foot.

The centrifugal force due to gravity alone at that position would have been

$$\sqrt{2g \times \tfrac{3}{4}} = 6{\cdot}928 \text{ feet per second.}$$

And if we now calculate the velocity of the force for projecting the body the $3\frac{1}{2}$ feet, and then subtract the previous rate, we shall arrive at the true velocity of the shock that it possessed over and above what was just sufficient to overturn the body.

By the formula

$$v^2 = \frac{a^2 g}{2 \cos^2 e\,(b - a \tan e)}$$

where $a = 3\frac{1}{2}$ feet, the horizontal distance.
$b = 7\frac{1}{4}$ „ the height of the centre of gravity.
$e = 39°$ the angle of emergence.

we get $v = 8{\cdot}364$ feet per second.

Now, subtracting 6·928 for the reason assigned above we have—

1·436 feet per second

as the projecting force which acted in addition to the overturning force. The latter we found previously to be 2·560 feet per second, and therefore by adding we get

3·996 feet per second

as the velocity of the wave particle at Jamalpur 74 miles from the seismic vertical.

It may be said that the smallness of the velocity, 1·436, just deduced, leaves very little room for fractional errors in the measurements which must always occur; but when we consider that it is certain there must have been some projection, certain, too, that it was only small, and when the conclusion here come to is corroborated by the next example, we have good grounds for thinking it correct.

The breaking of the chimneys.

In the previous case of the tomb we had to deal with objects which were considered as approximately rigid, or without any elasticity that need be taken into account; but coming now to the consideration of the chimneys, we have to bear in mind the very important fact that high brick-work structures of this kind are extremely flexible, and are capable of swaying through many feet in a high wind without breaking. What we have in fact is the case of an inverted compound elastic pendulum oscillating about a fixed point. If in such a building the greatest velocity that can be acquired by the centre of oscillation as it passes the vertical, during a maximum vibration, be greater than the velocity of the earth-wave shock in that direction, it is easy to see that the structure would not be forced to the limits of its flexibility and so would not be broken. If, again, they were about equal it would be a matter of uncertainty whether the chimney fell or not and in which direction it fell. But if the velocity of the shock were greater than the maximum velocity of the oscillation consistent with the elasticity of the chimney, the chimney would be broken in its weakest part during the first semi-phase, and the broken part would fall in the direction from which the shock came. In estimating, then, whether the velocity of any earthwave is sufficient to break a flexible structure such as a high chimney stalk, it is first necessary to know within what extremes the chimney can oscillate without breaking. For answering this question with rigid accuracy, many data respecting the modulus of elasticity of brick-work would be necessary, which are not at the present day determined satisfactorily. But there are other sources of information from observed oscillations of chimneys acted on by wind storms, which may be of use.[1] The Townsend chimney, over 320 feet high, was struck by a gale of wind which bent it beyond recovery 7 feet 9 inches out of the perpendicular, so that its length of oscillation without breaking was 15 feet 6 inches at the top. It seems probable, however, that if neglected it would have ultimately come down, for the deflection was observed to be increasing for some time whilst the workmen were straightening it. This chimney was more than twice the height of the mill chimney at Serajganj, but another one at Messrs. Matthews and Son's Chemical Works, Pitchcombe, was 132 feet high, or only 3 feet less than that at Serajganj, and like it octagonal in section. It was observed, when tested in 1875, to be 3 feet 10 inches out of the perpendicular, giving a range of oscillation without breaking

[1] See Supplement to Spon's Dictionary of Engineering, page 355.

of at least 7 feet 8 inches, at the summit. If we take 10 feet as the limit of possible oscillation of the mill chimney at Serajganj without breaking, we shall not be over-estimating it, since the Pitchcombe chimney was not so far gone relatively as the Townsend, and was easily straightened.

But first, as in the case of the tomb, it is necessary to get at the radius and centre of oscillation in order that we may learn what is the simple pendulum whose time of vibration corresponds to that of the compound pendulum of the chimney. By dividing the chimney into suitable lengths, and deducing the varying masses of these lengths from their mean internal and external diameters respectively, we can get their several moments of inertia about the axis of oscillation, and by adding them together get the moment of inertia of the whole mass.

This we find to be 407,414.

Having got this, it is easy to deduce the radius of gyration, and the radius of oscillation. The latter we find to be $69\frac{37}{45}$ feet from the base or nearly 70 feet. Thus the simple pendulum whose time of oscillation is the same as that of the chimney has a length of 70 feet.

Now, by the formula,—

$$t = \pi \sqrt{\frac{l}{g}}$$

where t = the time of oscillation; l = length of pendulum; and g = the accelerating influence of gravity in one second, we have

$$t = 3{\cdot}141 \sqrt{\frac{70}{32}} = \frac{8{\cdot}366}{5{\cdot}656} \times 3{\cdot}141$$

$$= 4{\cdot}647 \text{ seconds.}$$

Now, taking 10 feet as the range of oscillation of the summit of our chimney, we have $5\frac{1}{5}$ feet as the length of oscillation of the simple pendulum, 70 feet high, which represents it.

Then the greatest velocity attained during its maximum oscillation without breaking will be when it passes the vertical and will equal

$$\frac{5\frac{1}{5}}{2} \sqrt{\frac{g}{l}} = \frac{13}{5} \sqrt{\frac{32}{70}} = 1{\cdot}64 \text{ feet per second nearly.}$$

Now an earth wave shock at an emergent angle of 60°, and with the above horizontally resolved velocity, would have a rate of 3·28 feet per second along the normal, since sec. 60° = 2·0 and would cause just this oscillation. Therefore the velocity of the wave particle must have been just a little higher than this, or about 3·3 feet per second; for if it had been greatly higher, the chimney would have broken during the first semiphase, and its fragments would have been precipitated in the direction from which the shock came, whereas their actual position, as shown in fig. 2, Pl. I, declares that it was during the second semiphase that they were overthrown.

It might be thought that in that semiphase one-half the velocity afore-mentioned would have been sufficient, provided the period of oscillation of the chimney coincided with the period of vibration of the earth wave, but from the slow oscillation necessary for such a high chimney, 4·647 seconds, it will be at once seen that such a coincidence is impossible.

Putting together the evidence for velocity, we have the lowest and highest limits fixed by the Jamalpur tomb, 74 miles from the seismic vertical, at 2·56 and 23·22 feet per second respectively; and also a probable rate of nearly 4 feet per second deduced from the same data, whilst at Serajganj, 36 miles from the centre, we have corroborative evidence for a probable rate between 3 and 4 feet per second.

Small as this rate sounds to the ear, there is abundant testimony brought forward by Mallet in his report on the Neapolitan earthquake to convince everyone that its effects on badly built or unstable dwellings may be immense.

Velocity of transmission of the wave.

The data for obtaining this with accuracy are unfortunately wanting; such as there are being scarcely reliable as approximately correct. At Alipur Meteorological Observatory, Calcutta, the time of the shock was indeed fixed rigidly at 6 hours, 24 minutes, 12·6 seconds, but from only two other places, namely, Dacca and Sibsagar, have times been forwarded. From Sibsagar Observatory a seismometer form was received partly filled up, stating that a very slight shock of earthquake occurred there lasting about half a second, but that no seismometer cylinders were overthrown, and no damage done. The time given was 6 hours 48 minutes (local time), which corresponds to 6 hours 22 minutes Calcutta time. That is to say, the shock was felt 2 minutes earlier at Sibsagar than in Calcutta. Now allowing that the rate of transmission of the shock was twice as great (and this is the most liberal allowance possible) through the rocky strata towards Sibsagar as through the clay to Alipur, we still have more than double the distance for the shock to have travelled in the former than in the latter case, so that at least the shock should have arrived some little time later at Sibsagar than at Alipur. Thus we must put aside the time evidence here as unsatisfactory. From Dacca, a letter from the Traffic Superintendent of the Dacca and Maimensing State Railway, gave the time as 6·22 at the "last of the vibration" The time is telegraphed daily from the Government Telegraph Office, Calcutta; and was marked on the clock dial at the Dacca Railway Station accurately the day before. As Dacca is 35 miles, and Calcutta 158 miles from the seismic vertical they will be 57 miles and 164 miles respectively from the focus, reckoning the latter at 45 miles deep. Hence the difference in distance is 107 miles. This gives $53\frac{1}{2}$ miles a minute for the velocity of transit; a result much too large, even if some fraction of a minute be allowed for the vibration to have ceased at Dacca before the time was noticed.

On the whole, then, we have no reliable data that can in any way advance our knowledge concerning the velocity with which an earth wave is propagated through the rocks.

Minor earthquake shocks.

There seems to be no doubt that the forerunner of the destroying earthquake of the 14th July is to be found in the gentler, but still violent shock, of the 25th June, which convulsed a great part of Bengal, and was felt in Calcutta and Darjiling; whilst it is certain that the later small shocks and tremors have proceeded from about the same centre as that of the 14th.

These later ones happened on the following dates; and, though doing no damage, they kept the population in a constant state of expectant alarm:—

21st	July	about	5-10 P.M
22nd	"	"	4-30 A.M.
22nd	"	"	3-50 P.M.
23rd	"	"	3-30 A.M.
23rd	"	"	7-20 "
23rd	"	"	10-40 "
26th	"	"	5-30 "
26th	"	"	9- 0 "
26th	"	"	1-30 P.M.
4th	August	"	9- 0 "
5th	September	"	11-30 A.M.

Connection with Kashmir earthquake shocks.

On the 17th July at Murree a shock was felt, but this is no doubt rather to be relegated to the Kashmir set of earthquake shocks than to those of Bengal. And this brings us to the question whether there may be any connection between the two sets of earthquakes thus widely separated, or whether we are to look on them as due to causes working singly and unaided in their own localities. Doubtless there can be no definite answer to such a question, but it may be noticed that if we answer in the negative, if we put down their contemporaneity to mere chance, we tacitly admit that the causes of each are local, and by inference superficial. Hence we might find room in this case for the possible explanation offered by Mr. Medlicott in his preliminary notice of the earthquake, that the change in the course of the Brahmaputra and the consequent deposition of its vast sediment in a different area might have so disarranged the balance of the earth's crust and so brought on a bending in the strata that might have culminated in a violent snap sufficient to produce the phenomena of the 14th.

On the other hand, if we take their near coincidence in time as a sign of their connection in reality, we must look for no local and superficial cause, no mere change of a drainage system to account for them, but we must search for some deeper cause underlying the very roots of the mountains, and sufficient, by throwing the whole of the northern parts of India into a state of strain, to bring on earthquake phenomena in those parts of the earth's surface less able to stand the stress or more intersected by lines of weakness.

European earthquakes. Ischia, Krakatoa.

And in the same way if this relation be granted as probable, there seems no reason why the certainly marked increase of seismic and volcanic activity during the last year or so both in Europe and in some parts of Asia should not, in like manner, be due to some great underlying cause which, on a large scale, has been making itself felt here and there in weak places; now in Italy, now in Spain, now in England, Germany, Switzerland and Austria, and other places in the Eastern Hemisphere. Nor would it, perhaps, be too much to look back to the Ischian earthquake and the eruption of Krakatoa in the summer of 1883, as perhaps the great forerunners of this consecutive series of siesmic and volcanic phenomena.

In conclusion, I should mention that such observations as are recorded in

this paper are in a great measure due to the assistance I received from the Government officers at Sherpur, Maimensing and Dacca; and in an especial degree to the kindness and hospitality of several gentlemen residing at Serajganj, Suboinkholi, and Maimansing, without which, in a district destitute of hotels or dâk-bungalows a cumbrous camp equipment would have been necessary.

Report on the Kashmir Earthquake *of* 30th May 1885, *by* E. J. JONES, A.R.S.M., *Geological Survey of India.*

Exaggerated reports.—The newspaper and other reports of this earthquake, at first, as is usual in all such cases, much exaggerated the importance of the event.

Heavy loss of life.—But, in spite of the comparative mildness of the shock, the loss of life was very great, being in round numbers about 3,000. The cause of this is to be looked for in the very insecure manner of building in vogue. This, at the same time, has necessarily prevented the possibility of many accurate observations being taken from the ruins.

Style of building.—The greater number of the buildings may be divided into two classes:—

(i) those situated in the hilly parts of the country;

(ii) those situated on the more level country, in the wide portion of the valley of the Jhelum.

The first class are low structures, usually isolated, and frequently covering a large area of ground, being generally built upon a terrace on the side of a hill with one side resting against the perpendicular face of the terrace above. These huts consist of walls built of rubble loosely held together with mud; resting on these are a number of beams (roughly trimmed trunks of trees), which are also supported along their length by wooden posts; upon the whole of this with the interposition of some cross pieces of wood, a layer of dry mud is laid, which is added to year by year and forms a flat roof.

The second class are built either detached or several in a row; they consist sometimes of as many as three stories. The materials used in their construction are very various, blocks of dried mud measuring 2 to 3 feet in length, breadth, and depth and made in moulds *in situ;* sun-dried and burnt bricks held together with mud, or rarely in the case of the burnt bricks with mortar; rubble stones held together with mud. It is also usual in these buildings to place at intervals of 2 to 4 feet horizontal lengths of wood, and occasionally vertical and inclined ones; no attempt is made at bonding in these walls, and the mud between the bricks is about one-third the thickness of the bricks. Above this is placed a thatched gable-ended roof, into the composition of which heavy beams of roughly hewn timber enter very largely. The whole roof is supported on several square pillars of sun-dried bricks or other material carried above the walls and measuring 2 feet to 2 feet 6 inches along the side.

It will be readily understood that such structures are not of a nature to successfully withstand earthquake shocks, even when not of any great degree of

intensity. In a very considerable number of the cases in which huts were damaged, the supports of the roof had given way and allowed it to subside, frequently carrying the walls down with it and leaving only a mass of rubbish to indicate the spot where the house had stood.

Scattered through the country there are, however, a few buildings of a more substantial character, some of which were more or less injured by the shock.

Patan.—This village is situated on the road from Baramula to Srinagar, and near it is an ancient Buddhist temple, of which a view is given in the annexed plate. The temple is very nearly cardinal (*i.e.*, its four sides face nearly N-S. and E-W.), and is built of large trimmed blocks of limestone laid together without any cement. In each face there is an arched recess, and inside is a small open space about 10 feet square. From the western face three stones have fallen from near the top of the arch. The greatest damage was done to the S. and E. faces, especially at the S.E. corner, the greater part of which fell. The long axis of an ellipse drawn around the fallen stones as they lie upon the ground runs E. 22°S.–W. 22° N., which gives an approximate direction for the wave path at this point.

Srinagar.—In the Sher Garhi (the Maharaja's palace) the long walls of the large dining-room run east—west, and the one on the south side, which is an outside wall, consists of a series of brick pillars 3 feet wide with openings between them 4 feet 6 inch across. Three of the pillars are cracked; the two most decided cracks make angles of 27° and 37° respectively with the vertical, and are inclined towards the east. If we take the mean of these two, we obtain an angle of 32°, which, on the assumption that the fractures are formed at right angles to the line of shock, is equal to the angle of emergence of the shock.

A high wall outside this room and facing to the west was partially overthrown in a westerly direction into the court-yard. These two observations point to a wave path at this point in an E.–W. direction; and though the wall to some extent would have vibrated at right angles to its long axis and have fallen even under the influence of an oblique shock, yet the fissures in the pillars indicate pretty exactly the line of shock.

At the Sangin Darwázi, which is a gateway in the wall between the city and the Hariparbat fort, several stones have been thrown down from the top of the gateway in a more or less westerly direction, the only two whose original position I was able to discover had fallen to W. 1° N. and 12° N.; if we take the mean of these two, we get W. 6° 30′ N. as the direction from which the shock came. This gateway is built of brick with a facing of stone-work and looks towards W. 22° S.; on the eastern side of the arch a good deal of brick-work fell.

In the Tashwan division of the city is a bath-house, which is cardinal, and built of brick and mortar. Both the east and west walls of this building have fallen outwards, carrying some of the arched roof with them, and the west wall carried a small portion of the south wall with it. This indicates an east-west direction for the wave path.

Gondikallel.—At this small village, which is situated about half a mile to the west of Tregaon, near Shadipur, there was a small hut built of mud, the ends facing S.E. and N.E.; these ends both fell outwards, indicating a N.E.–S.W. direction for the wave path.

Mujigund—is on the left bank of the Jhelam, below Srinagar, nearly opposite Bakpura. Here there was a long building forming a stable belonging to the Maharaja; it was built of brick and mud pillars at intervals of about 6 feet, the spaces between the pillars being filled up with unburnt bricks. The long axis of the building ran N.–S. The whole of the walls, with the exception of the one at the south end, fell. The fall is reported to have taken place towards the east, but the debris had been removed in order to allow of its being rebuilt. This indicates a nearly E.–W. direction of shock.

Kaosa.—This village is situated on both sides of a small stream near Magaon. On the left bank is a large three-storied house of bricks and mud built in 1884, surmounted by heavy wooden beams for supporting the roof, which at the time of the earthquake had not been put on; these consisted of five cross beams resting on brick pillars and running N.W.–S.E., and one longitudinal ridge-pole above, running S.W.–N.E. The pillars on which these beams rested had been broken down, and the beams were lying on the floor of the attic; the longitudinal beam had moved 5 feet in a S.W. direction and 1 foot 8 inches towards N.W., the cross beams had moved in a N.W. direction 3 feet, and about 1 foot 6 inches to S.W. This would indicate a W.–E. direction of wave path.

Mágam (*Magaon*).—Here were three houses facing, respectively, N. 3° W., N. 8° W., and N. 18° W., the walls facing in these directions had all suffered the same damage, *viz.*, the mud which was used to fill up the intervals between the pillars of unburnt bricks had fallen outwards. If we take the mean of these three directions, we obtain N. 9° W. as the direction from which the shock came.

Makahama (*Harda Maka Nana*).—At this place the walls of the mosque, which were built of bricks and mud, were uninjured; but the pillars of brick-work above the walls, which were apparently intended to support the roof, though in this case they did not reach high enough, and the weight of the roof rested on wooden supports at the sides of the pillars, were damaged. The ends of the mosque face W. 17° S. and E. 17° N., the middle pillar at the west end fell outwards and the three middle pillars on the north side also fell outwards and one pillar on the south side was tilted inwards. This indicates a shock about diagonal to the building or W. 28° N.–E. 28° S.

Sopur.—The fort situated on the right bank of the river at the end of the bridge was considerably damaged. The component materials were rubble, cemented partly with mortar and partly with mud. It was a square building with a tower at each corner, the towers being portions of octagonal pyramids built on to the corners which point N., S., E., and W., and in the middle of the S.W. side was a square gateway tower. Inside, on the ground, there were several cracks running N.E.–S.W. On the S.W. side the top of the gateway tower fell inwards; the same occurred to the south and west corner towers; on the S.E. wall a portion fell near the east tower in a S.E. direction, and the east tower fell entirely. Several portions of the N.W. wall, and a considerable portion of the N.E. wall fell. The roof of a small hut just outside the gate was thrown off to S. 13° E., bringing down the walls at the same time. All this indicates a shock from a direction somewhat to the east of south.

Chikar.—This is a fort situated above the Jhelam some distance to the south

in the neighbourhood of Garhi; it is built of rubble and mud, with horizontal wooden beams at intervals of 2 feet and a mud plastering over the whole. The building is square, with portions of octagonal pyramids forming towers at the corners and in the middle of three of the sides; on the east side there is a square gateway tower. A portion of the east corner of the S.E. tower fell down towards the east and a portion of the N.W. tower fell to the west. This gives an E.–W. direction for the shock at this point.

Position of the seismic vertical.—Tabulating the above we get—

PATAN—	
Temple	E. 22° S.—W. 22° N.
SRINAGAR—	
Sher Garhi	E.—W.
Sagin Darwazi	W. 6° 30′ N.
Tashwan	E.—W.
GONDIKALLEL—	
Small mud hut	S. W.—N. E.
MOOJIGOOND—	
Stable	E.—W.
KAOSA	E.—W.
MAGAM (MAGAON)	N. 9° W.—S. 9° E.
MAKAHAMA—(HARDA MAKA NANA)	W. 28° N.—E. 28° S.
CHIKAR Fort	E.—W.
(SOPUR Fort	S., some degrees E.)

Plotting these directions on the map, we find 17 intersections within a circle of 4 miles radius round a point quarter a mile S.W. of Jampur, 12 miles from Srinagar in a westerly direction from the northern end of the city; and 21 intersections within a radius of 10 miles round the same point. Considering the class of buildings from which the observations were necessarily taken, this gives as accurate a determination of the position immediately above the seismic focus as could be expected. This position agrees sufficiently well with the results obtained at Sopur, which were not plotted owing to the indefiniteness of the indications.

Residency at Srinagar.—The walls of this building, which is situated on the right bank of the Jhelam to the east of the city, were fractured in such a way as to indicate a shock very nearly N.–S. This is possibly due to a reflection of the shock from the inlier of older rocks which lies to the east of the town; but as the fractures were mostly old ones that had been plastered up previously, they are not of a nature to give satisfactory indications.

Baramula.—At Baramula also everything tends to show that the shock was there N.–S., walls facing north and south being overthrown, and those facing east and west fractured. This also is probably due to a reflected wave from the hills to the north of Baramula.

Depth of the seismic focus.—We saw that at Srinagar the angle of emergence was 32°. Now the depth of the focus is obtained by the formula—

$$d = r \tan. e$$

where e = angle of emergence at any point, and r = distance of that point from the seismic vertical, we have therefore—

$$d = 12 \times \tan. 32^\circ$$
$$d = 7{\cdot}5 \text{ miles}$$

which in the absence of other data from which the depth might be calculated may be taken as an approximation to the mean depth of the seismic focus.

Meizoseismal area.—The greatest damage has been done over an irregularly elliptical area, the long axis of which is 10 miles and the short axis 6 miles long, and the superficial area about 47 square miles, and nearly symmetrically disposed about the seismic vertical. Within this area, marked by a broken line (— — — —) on the maps, the destruction was very complete, whole villages being almost entirely destroyed and many lives lost. This corresponds to the meizoseismal area of Mallet.

First isoseismal.—The area outside this, corresponding to Mallet's first isoseismal, includes the area within which large portions of villages and towns were thrown down and persons killed. This is included by a line passing east of Srinagar through Magaon south of Baramula and across the Jhelam near Gingal, then passing north of Sopur and round again to the south of Srinagar. It includes an area of about 500 square miles.

Second isoseismal.—Outside is again another area of about 3,000 square miles including those places from which slight damage to buildings, &c., is reported to have occurred, but it is probable that even within this area there was some loss of life. It is indicated on the map by the broken line passing north of Gurais, from thence it passes east of Titwal on the Kishengunga river, west of Chikar, south-west of Bagh, and south of Púnch, at or near all of which some damage to buildings, chiefly forts, is reported. From Púnch to Gurais there are no reports, and the true course of the line is uncertain.

Third isoseismal.—This is a large area: including the places where the shock is reported to have been perceived by the unassisted senses, *viz.*, Peshawar, Gilgit, Simla, Sabathu, Dalhousie, Lahore, &c.

Outside the third isoseismal area is a larger area, the extent of which is quite unknown. It is that in which the shock might have been perceived by means of properly constructed instruments.

Sound accompanying the shock and preliminary tremors.—A sound, which is variously described as resembling distant thunder, a discharge of artillery, and the noise caused by blasting operations, preceded the shock, and seems to have been noticed by many who were not asleep at the time; but no preliminary tremors seem to have attracted attention.

Transit velocity of the wave.—No observations of the time at which the shock was felt were made with any instruments sufficiently accurately adjusted as to give any reliable data for calculating the transit velocity.

Velocity of the wave particle.—I was not able to find any objects overturned or projected in such a way as to give a measure of the velocity of the wave particle, but considering the class of buildings which have escaped, it cannot have been very great; for almost the whole of the buildings are either bad, ill-laid and ill-cemented masonry, or simply mud structures; and we know that a horizontal velocity of 3 to 4 feet per second is sufficient to fracture such structures.[1]

Landslips.—Several secondary effects of the earthquake were noticed.

[1] The Neapolitan Earthquake of 1857, Mallet, Vol. II, p. 346.

A large landslip occurred at Larri-dur, a place about 7 miles south of Baramula. This village was situated upon a hill lying N.W.—S.E., composed of slightly hardened Karewa[1] clays resting upon sandstone and dipping to N.E. at 5° to 10°. Above the clay is surface soil of varying thickness. The upper 30 feet of clay and surface soil has slipped along to the dip, exposing a fresh smooth surface of clay. The line of parting ran along the length of the hill, and a fissure has been formed along this line varying in width from 30 feet at the S.E. end to about 500 yards at the N.W. end, and with a length of about half a mile. To the N.E. of the narrow end of the fissure another slip has taken place from the side of the hill. The mass of clay and surface soil that has slipped is all piled up to N.E. of the hill in the little valley situated there, and all the huts that lay in its path were of course buried.

The slip was probably due to the presence of water in the clay, which must have accumulated along the plane of bedding, thus producing a soft water-saturated stratum over which the upper mass would readily slide. With the upper mass thus situated, floating as it were on a layer of slime, a slight shock might be quite sufficient to fracture it and cause it to slide by reason of its own inertia.

Fissures and sand craters.—In many places, as at Patan, Dubgaon (at the junction of the Jhelam and Pohra rivers), along the banks of the river at and above Baramula, numerous fissures were formed in the alluvial soil, of no great width (none exceeding a yard across) and all running roughly parallel to river banks or else across the slope of hills.

In the neighbourhood of many of these fissures water and fine sand were thrown out, and the villagers stated that there was a strong sulphureous smell given off from the sand for several days. This smell was probably due to sulphuretted hydrogen gas ($S.\ H._2$) produced by the slow decomposition of the strings of vegetable matter imbedded in the alluvial soil. In one case at Nila, near Patan, I saw an inflammable gas without odour being slowly evolved. This was probably marsh gas ($C.\ H_4$) or one of its homologues, produced in the same manner.

Effect on springs.—Several springs were affected by the earthquake, the flow of water being increased for periods of time ranging from a few hours to as many as eight days.

The country occupied by the meizoseismal area is entirely composed of recent alluvium, and that within the first isoseismal line is almost entirely of the same character, the Karewa beds (pleistocene alluvium) coming into the N.W. of the area in the neighbourhood of Baramula, and down the river below Baramula the alluvial deposits are underlaid at a short depth by the more indurated rocks of the Panjal system, which also appear to the east of Srinagar.

Subsequent shocks.—The slight shocks subsequent to the great one continued at intervals up to as late as August 16th, on which date there was a shock at about 7 A.M., since that time I have seen no reports, though the shocks probably continued to a much later date.

Desirability of erecting seismometers.—In a country like Kashmir, subject as it is to earthquake shocks at frequently recurring intervals, it would be highly desirable, especially in the absence of buildings suitable for seismological observa-

[1] Old lacustrine or fluviatile deposits now eroded into plateaus and terraces.

tions, to have at one or more stations seismometers erected, and should this for any reason be found impossible, it might still be practicable to erect at several points masonry pillars surrounded by a rough wooden fence and placed in charge of the headmen of the villages if necessary, which, if overthrown or fractured by an earthquake shock, would to a great extent supply the place of ordinary seismometers.

In conclusion, I would thank Colonel Sir O. St. John, K.C.S.I., R.E., the officer on special duty in Kashmir, and all the officials of His Highness the late Maharaja of Kashmir and Jamu with whom I came in contact, for the assistance rendered me during my stay in Kashmir and without which it would have been almost impossible to carry on the investigations.

Notes on the results of MR. H. B. FOOTE'S *further excavations in the* Billa Surgam Caves, *by* R. BRUCE FOOTE, F.G.S., *Superintendent, Geological Survey of India.*

The further exploration of the Billa Surgam bone caves during the season 1884-85, by Lieutenant Foote, R.A., have been rewarded with a rich collection of fossil bones, together with many traces of the contemporaneous existence of man in the form of rather rude bone implements and other cut bones of great interest.

Lieutenant Foote resumed work at Billa Surgam in December last, and continued at it till the end of May. Previous to his return to military duty, he spent a few days with me, assisting me in unpacking the collections he had made, and explaining various points connected with his work. He subsequently drew up an interesting report of the work effected, much of which will be quoted further on.

With reference to the condition in which he found the caves on his return in December (1884), he reported: "I found everything just as I had left it at the end of May previous. The north-east monsoon having failed, the spoil banks were untouched, so I could not judge whether the stream which flows through the caves in wet weather is of any size."

Order in which the work was pursued.

"On first re-commencing operations, I determined to finish off the layer C c in the south corner of the Cathedral cave, and also the remaining cave earth in the Charnel House before proceeding to excavate over the whole area of the Cathedral."

"When the Charnel House cave was finished, as I had as many men at work in the Cathedral as I cared to have, I set the Charnel House gang to dig in the small cave which opens into Chapter House on the side. The results obtained will be given further on."

The Garden.

Mr. Henry Foote further examined, at my special request, the little grass-grown patch—"the garden"—on the cliffs above the north Chapel cave, as it seemed a very likely place to have been resorted to by possible cave dwellers as a strong terrace well suited for cooking and for basking, and whence they could keep a good look-out against sudden attacks from enemies. The little terrace was completely dug over down to the rock, but

yielded nothing of interest. No further excavation was attempted in the Purgatory cave.

Further excavations in the Cathedral.

The second series of excavations made in the Cathedral cave was much less easy to effect than the first, as he had to contend with great masses of hard stalagmite, much of which had to be blasted, while the rest was broken up with cold chisels.

Discovery of further passages and chambers.

The excavation of the whole area of the Cathedral cave was effected to a depth of 16 feet, and in the southern corner a wide shaft was sunk to a further depth of 21 feet, making a total of 37 feet from the original surface. The sinking of this shaft revealed the existence of a passage opening from the south. This passage, to which the name of the "Corridor" was given, was followed up, and at a distance of 55 feet southward of its mouth was found to lead into another larger passage running east and west.

The Corridor.

On the south side of this east and west passage, and opposite to the mouth of the Corridor, another passage was found running south apparently, but for want of time not excavated.

The Fairy Chamber.

The east and west passage formed a domed chamber, measuring, before the excavation of its floor was commenced, 25 feet by 12 feet, with a height of 10 feet in the centre. A large fine stalactite hung from the centre, and below it was a large mass of stalagmite, the off-flow of calciferous water, from which had formed a stalagmite crust from ½ to 1 inch thick over the floor of the chamber. At the eastern extremity of the chamber the roof of the cave sloped down to about 2 feet from the floor, and here occurred "a perfect forest of most beautiful little stalactites, some forming delicate little pillars, others branching off into tree-like forms as ramified as the most elaborate corals." To this chamber Lieutenant Foote gave the name of the "Fairy Chamber" after the beautiful little cave at Caldy, in Pembrokeshire, so graphically described by Professor Boyd Dawkins in "Cave-hunting." The western end of the "Fairy Chamber" was filled with cave earth, which proved very rich in good specimens, as did also that in the "Corridor." The atmosphere in the Fairy Chamber was extremely close and steamy, and it was impossible to be in it for many seconds without being bathed in perspiration.

Section of beds in the Cathedral.

The series of beds exposed during the excavation of the Cathedral cave is given below in tabular form. The several layers in which the thicker beds were taken out, and the marks with which their fossil contents were registered, are also shown:—

9. Surface, or bat's dung, bed		C		Average thickness . 3′
8. Grey sandy bed, with some bat's dung		C		3′
7. Stalagmite in irregular masses		.		—
6. Red sandy cave earth		C a		3′
5. Stiff red clay	excavated in three layers of 3′ each	,, b	9′	3′
		,, c		3′
		,, d		3′
4. Stiff dark marl		,, e	6′	3′
		,, f		3′

3. Dark loamy marl	C h		3′
2. Grey marl	" i " j	6′	3′ 3′
1. Grey marl	" k " l	6′	3′ 3′

Of the above formations everything down to the base of 5 (C d) was entirely removed, and the underlying formations were exposed in a wide shaft sunk in the south corner of the cave (to a depth of 37 feet from the surface); the average thickness of the mass removed over the whole area of the cave was 16 feet. The beds showed a general low dip north-westward.

With reference to the surface (bat's dung) bed, Lieutenant Foote states:

Surface bed.

"This bed varied very much in thickness, being 4 feet thick behind the high altar and only 1 foot thick on the north front of the cave, but it increased again on the south front, until behind some of the stalagmite masses in front of the high altar it attained a thickness of 6 feet. There were many small bones in it, most of which had lost their gelatine."

Bed C.

Of the upper bed of grey sandy cave earth (C,), he remarks it "is much infiltrated in places with colouring matter, and at the top a good deal mixed with bat's dung—in fact to the presence of the latter I attribute the grey colour of the earth, which would otherwise have been nearly white from calcareous infiltration. The stratification was "very indistinct. There were very few large bones found, but plenty of small ones, which had all lost their gelatine but were not mineralized."

Stalagmite barrier.

"Before excavating the next layer (C a), I had to remove the barrier of stalagmite across the cave; the softer blocks I broke up with cold chisels, but the great majority had to be blasted; and in all I removed some 50 tons of rock."

Layer C a.

"C a, as I termed the next layer of earth, was a red sandy bed about one yard thick, but in the front of the cave it was considerably thicker in places owing to the stream (flowing from the back of the cave) having scooped out channels in the underlying red clay which were filled up with the sandy bed."

"This bed partly underlies the high altar, and also contains a good many blocks of limestone—in fact in front of the altar it was entirely replaced by the basement blocks of the stalagmite barrier which here formed a regular floor. Many of these blocks of stalagmite are *in situ*, and as they are of large size, (some being 4 or 5 feet high), the underlying cave earth (C b) must be of great age, as, owing to the very dense nature of the greater part of these blocks, they must have been formed slowly."

Referring to the red clay bed $\left(C \begin{smallmatrix} b \\ c \\ d \end{smallmatrix}\right)$, Lieutenant Foote writes:—"Another

Bed C $\begin{smallmatrix} b. \\ c. \\ d. \end{smallmatrix}$

fact which points to the great age of this clay bed is that its surface is covered with a regular pavement of fallen blocks of limestone; and as most of them are small, they would seem to be rather the result of the slow breaking up of the roof owing to weathering than of any sudden disturbance of the rock by earthquakes.

Layer C c.

The layer C c of the red clay was found to be very rich in teeth in places, but very poor in front of the high altar. Like the overlying layer, this becomes much more sandy as it goes back behind the high altar; and as it becomes more sandy, so are the large bones and teeth replaced by small ones. With regard to these beds being rich in some parts in small bones, which are almost entirely absent from them in other parts, I would suggest that it is most likely owing to the bed being higher behind the high altar than elsewhere, it might therefore have been high and dry there when the other parts were under water, and consequently it would have been chosen as a resting-place by the owls, &c., which came to make their castings in the cave.

The surface of the underlying dark marl bed $\left(C\,{}^{e}_{f}\right)$ was found to have been scooped out by stream action to a depth of some 2 to $2\frac{1}{2}$ feet; and where this had been the case, the overlying red clay was by so much the thicker than elsewhere. The excavation of C d brought to light the mouth of the Corridor passage leading southward into the Fairy Chamber, into both of which the red clay extended and maintained its character for richness in fossil remains.

C d yielded nearly all the important large bones found, and, excepting C b, was richest in small bones as well. Of cut bones C d yielded nearly twice as many as all the other beds together.

The several beds penetrated by the shaft sunk by Lieutenant Foote after clearing out the whole of C d and all above it, were of much less interest than the red clay above them, from the fact that they yielded but few good bones and teeth, most of the tolerably numerous fossils being fragmentary.

Bed $C\,{}^{e.}_{f.}$

In this respect the lower half of the dark marl bed $\left(C\,{}^{e}_{f}\right)$ was better than the upper, which contained little but fragments of teeth, many being parts of molars of Rhinoceros.

Bed C h.

The underlying dark loamy bed C h was fairly rich in small bones, amongst which many belonging to different genera of birds.

Beds $C\,{}^{i.}_{j.}$ $C\,{}^{k.}_{l.}$

Of the remaining beds, C i and C j became increasingly poor in bones, while C k and C l are, to all intents and purposes, sterile, so much so that Lieutenant Foote does not consider them worthy of further exploration.

In the front portion of the Charnel House cave, where Lieutenant Foote had in his first exploration reached a depth of $27\frac{1}{2}$ feet, he descended through 8 feet of stiff grey marl to the bottom of the cave at a total depth of $35\frac{1}{2}$ feet from the original surface. No bones were found in this grey marl.

At the eastern or inner extremity of the Charnel House the passage widened out somewhat as followed eastward, and at the crossing of two master-joints in the limestone formed a star-shaped well (in plan), from which 18 feet of stiff red-clayey earth had been removed. At a depth of 27 feet the passage widened out in the cross joint and could have been entirely cleared; but as this would have involved costly timbering to shore up the sides, and the cave earth was very sterile, Lieute-

nant Foote judged it wiser simply to sink a pit in the centre of the cave, which was from 5 to 6 feet wide. The sinking was effected in depths of a yard each till a depth of 58 feet 6 inches was reached when the passage contracted suddenly from 5 feet to 6 inches and could be followed no further.

The results obtained by the excavation of the little cave on the south side of the Chapter House were small, the only point of real interest was that of a large human molar in a bed of red cave earth about 4 feet below the surface, the only human bone found anywhere in the true cave earth. The red cave earth was overlaid by black gravel from 1 to $1\frac{1}{2}$ foot thick.

Absence of skulls.

A remarkable fact, not easy of explanation, is the almost total absence of the skulls of the animals whose bones are met with in the caves. With the exception of two or three tolerably perfect skulls of bats which live in the cave, no entire crania or large fragments of crania were found, though many mandibles or rami of mandibles with or without their teeth were met with, from those of Rhinoceros down to those of minute shrews and rodents, &c. Teeth of many genera, especially ruminant and rodent, were obtained in considerable numbers, and mostly in excellent preservation.

A fairly large number of genera not found during the first exploration have now to be added to the preliminary list of the cave fauna, especially among minute mammals, birds, and reptiles.

The working out of the remains obtained at Billa Surgam will furnish materials for a very valuable chapter on the prehistoric fauna of South India, though the anthropological results so far obtained are rather disappointing from their negative character.

Preliminary list of fauna.

The following is a tentative preliminary list of the fauna of Billa Surgam, including some additional forms not found in the first collection made. These have an asterisk prefixed to their names.

MAMMALIA.

Presbytis (Semnopithecus) priamus ?
Macacus ? sp.
Chiroptera, several.
Sorex sp., small.
Tupaia ? sp., small.
Ursus ? sp.
Felis tigris.
 Do. pardus ?
 Do. sp., medium sized.
 Do. sp., small.
Viverra zibetha ?
* Paradoxurus ?
Herpestes griseus ?
Canis sp.
Sciurus ?
Mus sp.
* Nesokia sp.
Hystrix leucurus.
Lepus sp.

Rhinoceros sp.? javanicus. A possible second (smaller) species is suggested by difference in size and shape of posterior upper molars.
* Equus sp., large.
Do. sp.? small.
Sus indicus.
Rusa aristotelis.
Axis maculatus.
* Cervulus aureus?
Memimna.
Antilope bezoartica?
* Gazella bennettii?
Portax pictus.
Capra?
Ovis?
Bos sp.
Gavæus?
* Manis pentadactyla.

AVES.

Genera belonging to the orders Grallatores, * Rasores,
* Scansores?, * Insessores, and Raptores.

REPTILIA.

Crocodilus sp.
Varanus dracæna.
Agama?
Lacerta?
* Ophidia, several sp.
* Emys sp.
* Phelone sp.

AMPHIBIA.

Rana sp., small.
Ditto sp., very large.
Bufo?

In their mode of occurrence, the bones, &c., collected during Lieutenant Foote's second season presented the same features as those of the first. Most of the bones and teeth occurred detached, and many of them had been cut or broken before being entombed in the several caves. Of the few large bones found, the most important belong to the genera Rhinoceros, Bos, and Equus.

Of the larger teeth collected, there are a fair series of Rhinoceros and Equus. Of bovine ruminants, of Sus and Hystrix many teeth were collected. Very large quantities of small bones left in the caves by birds of prey making their castings were found in almost all the layers of cave earth removed, as was the case in the earlier excavations.

No signs of continued residence of man or large animals.

As before, no traces were found of the continued residence of man or of large carnivora in any of the caves. No cooking-places of any size were found, though here and there scraps of charcoal or a little ashes occurred, nor was any pottery met with in any of the lower lying beds. Only very few calcined or charred bones were found, and they were in the superficial deposits of the Cathedral and Purgatory.

As in the Charnel House the bones found in the Cathedral were washed in

from behind through passages communicating with the surface of the plateau above, and the main stream flowing through the body of the Cathedral cañon seems to have deposited only barren strata of sandy and stony character.

Of the streams which filled the Cathedral, one flowed in from the east, entering the apse close to the north side of the high altar, the other entered from the south through the Corridor. It is not improbable that another passage entered the apse of the Cathedral from the south-east, but is now hidden by the great stalagmitic mass of the high altar.

Bone implements.

Of the cut bones a considerable number are so shaped as to necessitate the conclusion that they were fashioned for special purposes; others, and they are much more numerous, though often elaborately cut, are so vaguely shaped that it is hard to conceive their having been prepared for any definite object; they rather suggest the idea that their fashioners were simply amusing themselves as they whittled them.

Nondescript cut bones.

Besides these trimmed bones most of the large bones found, and many of the smaller ones as well, show signs of man's agency in having been cut and scraped, and often to a great extent.

All the large bones had been set aside and registered as they were exhumed in the caves, also a large number of smaller bones and teeth; but a more careful examination of the numerous parcels of small bones brought from Billa Surgam, which examination could not be undertaken on the spot, has yielded many hundreds more of important bones and teeth and cut bones of medium and small sizes. There can be no doubt, however, that yet many more will reward the exhaustive examination, to which they will have to be submitted by the pal-osteologist, by whom the whole series of 'finds' is to be worked out finally.

Census of the selected specimens.

A census of the selected and registered specimens shows them to number 4,700 in round numbers, of which 3,000 are bones or teeth and the rest cut and trimmed bones. Of these latter some 200 may be considered to represent real implements prepared with a definite purpose. Of the remainder it is hard to say with what object they were trimmed into the shapes they now show.

Cuttings probably effected with stone implements.

None of the implements with which the cuttings were effected were met with in the caves, but from the peculiarity of the cut surfaces which are very scratchy, not clean and smooth, it is difficult to resist the inference that the implements used were not made of metal but of stone. The cuts show that the implements were used much more with a sawing or heavy scraping action than with a chopping one. None of the bones, so far as I have examined them, show the splitting off of chips beyond the cut which invariably accompanies the action of heavy metal implements.

Bones showing the marks of teeth of carnivora are not very numerous, nor do many show the grooved markings made by the teeth of rats and other rodents.

No stone implements found.

As stated above, no stone implements were found, though Lieutenant Foote, who is quite familiar with such antiquities, devoted very special attention to the search for them and examined personally many thousands of stones turned up during the

excavations, besides exhibiting typical implements both palæolithic and neolithic to his diggers. One possible implement may be admitted in the shape of a tiny triangular flake of transparent quartz found by Lieutenant Foote during his first season at the caves. Such flakes have unquestionably been converted into drills by neolithic and other peoples.

Character of bone implements.

Among the worked bones shaped for specific purposes, the following forms appear to be recognizable :—

Awls.
Arrow heads, unbarbed.
Ditto with one barb.
Spear or harpoon heads, small.
Dagger.
Scraper knives.
Scrapers.
Chisels.
Gouge.
Wedges.
Axe heads.
Sockets, double, large and small.
Ditto, single.

The most remarkable of these implements is the gouge, already described in my second paper on the caves, and the dagger which is made of the calcaneum of some large (ruminant ?) animal. The calcaneum proper is the handle, and the narrow blade of the implement is cut out of the united fibula and tibia. It would be a formidable weapon in the hand of a strong man.

None of the supposed arrow or harpoon heads show more than one barb, which appears always to be basal, but a number of them are rudely waved as if anticipating the Malay Kriss. The supposed whistle is a digital bone, apparently of an antelope, of which the distal end has been cut off. It is not an effective whistle, and might very possibly have been intended as a handle to some small boring implement.

These cut bones are being sent to Europe together with the other cave treasures, as no collections of prehistoric bone implements exist in India with which to compare them.

A single cylindrical bead fairly well shaped, made of some dark brown material (possibly bone), was found in the upper layer of cave earth C in the Cathedral cave ; it was associated with numerous bones but no other articles of human workship. The perforation of the bead is well drilled, and the aperture at each end slightly enlarged by the use of a larger sized drill.

It is impossible to describe these implements more fully unless they were figured, which I trust they will be in the full memoir to be drawn up about the Kurnool caves.

Advisability of further exploration.

As to further explorations of the Billa Surgam caves, I think the excavations should certainly be continued so far as to remove the remainder of the red clay C d from the Corridor and Fairy Chamber. Further exploration of the Billa Surgam and

other caves should be carried out by a prehistoric Archæological Survey Department, for which there is a very large field of work in the south of India.

Other caves visited.

Several other caves being known by report in other parts of the Kurnool District, of which it was desirable to have some positive information, Lieutenant Foote and I devoted the Christmas week (1884) to visiting them. The following caves were seen by us:—

1. A group of small caves lying 3 miles north of Billa Surgam, and known as the Boganpalli caves.

2. Two small caves lying south-west of Owk, in the south-western part of Koilkuntla Taluq.

3. A little cave in the centre of the village of Billam, in Banaganpalli State, and exposed at the bottom of a well.

4. A large and important cave about a mile south-west of Billam village.

5. A deep well-like chasm into which a long flight of steps descends to the sacred spring of "Nela Billam," about 6 miles north-east of Tarpatri. The two Owk caves, the little Billam cave, and the "Nela Billam" cave, are full of water in their lower passages as far as we could explore; but the great Billam cave is in wet weather a subterranean water-course traversed by a furious torrent.

Two other caves west of Gorlogunta, near Billa Surgam, were visited by Lieutenant Foote early in 1884. Of all these caves the Boganpalli group alone seems to promise good results to future explorers.

In conclusion I would remark that Lieutenant Foote carried out his work with great zeal and tact, and no little devotion to duty, for he was working in a desolate out-of-the-way valley out of reach of civilisation and all society. For, excepting myself for a few days, he saw no European for months together, which is no small trial to a young man fresh from all the gaiety and life of Bombay.

Besides the excavation work Lieutenant Foote took a number of very successful photographs of the Billla Surgam and other caves which he had not been able to do with the large wet-plate camera lent him by Government during his first season.

On the mineral hitherto known as Nepaulite, *by* F. R. MALLET, *Superintendent, Geological Survey of India.*

In 1853 a rather large collection of rocks and minerals from Nepál was presented by General Jung Bahádur to the Asiatic Society of Bengal. The greater part of these were found by Mr. H. Piddington, Curator of the Society's Museum of Economic Geology, to be of no value, but one ore attracted his attention as being unfamiliar, and was subjected by him to examination and analysis.[1] The mineral was said to have been found in considerable quantities not far from Khatmandu, and, being easily fusible, to have been used for casting into cannon balls, which, however, flew to pieces on being fired. Mr. Piddington described the mineral as a carbonate, mainly of bismuth, copper and iron, and pronouncing

[1] Jour. As. Soc. Bengal, Vol. XXIII, p. 170.

it to be a new species, gave it the name of 'Nepaulite,' from the country whence it had been sent.' The analysis given by him is as follows:—

		Metallic about
Sulphur	1·60	
Silex	3·60	
Carbonate of Protoxide of Bismuth	31·80	24·6
Carbonate of Copper	22·96	14·40
Per-Carbonate of Iron	25·62	9·21
Ox: Cerium	9·40	
Lanthanum?	2·80	
	100·78	

Also traces of silver.

Mr. Piddington described the mineral as having a metallic lustre. "In external appearance it resembles exceedingly some of the varieties of granular and massive plumbago, or antimonial ores, which, at a first glance, and where the quartz matrix has no blue stain, it might well be mistaken for. The fresh fracture is of course somewhat brighter and more steely than the old surface, which like that of the plumbago ores is of a duller black, though always with a good metallic glance." But he makes no allusion to the remarkable peculiarity that 'Nepaulite' differed in this respect from all previously known native carbonates, the lustre of which is, without exception, non-metallic. This fact was in itself sufficient to cause some suspicion as to the correctness of the analysis given.

In 1866 the geological and mineralogical collections of the Society were handed over to Government, and in 1876 were transferred to the Geological Museum. During the arrangement of our economic collections I submitted the specimens in question to an examination, which, though very partial, was sufficient to prove that the ore contained a large proportion of sulphur, and also of antimony, and that the analysis quoted above could not possibly be correct. It is, however, only recently that I have been able to examine the substance more completely.

The mineral has a metallic lustre, iron-black colour, and dark brown streak slightly tinged with red. It is uncrystallised, and occurs irregularly through a somewhat translucent quartz-rock, which has a granular structure, with apparent traces of foliation, suggestive of its being a metamorphic quartzite rather than a true vein-stone. Azurite, malachite, melaconite, cervantite, smithsonite, ochre, calcite, &c., occur in association with the sulphide ore, most of them being probably results of its alteration. The sulphide is so mixed up with the gangue that it was only by laborious picking that enough could be separated for an analysis, which gave—

Sulphur	21·12
Antimony	25·17
Arsenic	1·32
Copper	33·69
Silver	traces
Lead	·30
Iron	5·33
Zinc	2·44
Calcium carbonate	1·07
Magnesium "	·13
Insoluble gangue	·68
Oxygen, carbonic acid, water & loss	8·75
	100·00

The oxygen, carbonic acid, and water are due to malachite, azurite, and melaconite, from which the sulphide ore could not be wholly freed. Cervantite was also not improbably present in small quantity, although, like the calcium carbonate, not visible to the eye. The number of minerals of apparently secondary origin in association with the sulphide, and the somewhat large proportion in which they occur, seem to indicate that the specimens were obtained from near the surface. Hence it is not unnatural that the sulphide should be in a somewhat altered condition. As an indication of the exact composition of the fresh and unchanged mineral, the analysis is therefore unsatisfactory, but it suffices to show beyond all doubt that the mineral is tetrahedrite of a common type. The above figures correspond to the formula $R_4 (Sb\ As)_2\ S_6 = R_{4\frac{2}{3}} (Sb\ As)_{2\frac{1}{3}}\ S_7$, the excess of metals over the proportion required for the formula $R_4 (Sb\ As)_2\ S_7$ being certainly in part, and probably wholly, due to the occurrence of some of them partly in an oxidised state, owing to the alteration of the mineral just alluded to.

Considering the wide discrepancy between the preceding two analyses, the idea may perhaps suggest itself that they refer to altogether different specimens. But those which I examined were handed over to Government direct from the Asiatic Society's Museum; they agree in their general outward appearance with the description given by the author quoted, and when they came into our possession the word 'Nepaulite' was found marked upon them in oil paint.

Notice of the Sabetmahet Meteorite, *by* H. B. MEDLICOTT, *Geological Survey of India.*

Sabetmahet is a small village in the Gonda district of Oudh, close to Muthuraghat on the Rapti, about 11 miles north-west of Balrampur, approximately at 82° 7′ E. Long. and 27°-35′ N. Lat. The fall occurred on the evening of the 16th of August 1885. The stone is an average oligo-siderolite, *i.e.*, having but a moderate admixture of meteoric iron, and so, under the circumstances explained in the following extracts of correspondence, there was no occasion to press the claim for surrender. The weight of the whole stone is given as 2 lbs. 13·77 ounces (1297·04 grammes). A very small portion was sent as a sample—

Larger piece	1·52	grammes.
Smaller piece	·52	"
Minute fragments, aggregating	·80	"
Total .	2·84	grammes.

The record is only worth publishing to illustrate what honour meteorites receive among our "Aryan brothers" of the period in Hindustan. The story moreover exemplifies a universal evil—the influence of priests and through them of women in dragging men to superstition: yet,

Das Ewig-Weibliche
Zieht uns hinan.

Extract of a letter from the Deputy Commissioner of Gonda, dated 5th September 1885.

"The stone was brought in from Balrampur piously wrapped in a cloth and carried by Brahmans. It was decked with flowers and it had been daily smeared

all over with ghee [clarified butter] which made the smooth exterior look quite the colour of iron, and it had been subjected to frequent puja [ceremonial worship] and coatings of sandal wood powder, which latter I carefully washed off. The villagers, where it fell, had started a subscription to build a shewala over the aerolite, which was looked upon as a Mahadeo, and the Maharani with her accustomed liberality had promised money assistance for the construction of the shrine. * * * * * *

"In the present instance I can very clearly see that to take this aerolite from the superstitious villagers who have obtained possession, and who have been for days doing puja to it, would cause to them the most profound disappointment and sorrow. I believe, too, the Maharani on whose estate it fell having evinced her superstitious sympathy by giving a money subscription would with the people feel hurt if the aerolite were appropriated by the Government."

Extract from the evidence of the man who saw the stone fall and dug it out; attested by the Deputy Commissioner, dated 3rd September 1885.

"On Sunday, at a quarter after 5 P.M., I made over the stone to Gur Purshad Goria and went home. It was of a kunkur colour up to that time [no doubt from adhering clay]. Next morning people assembled, and Mahesh Pandit also came. Gur Purshad washed the stone; the Pandit then said that he (Gur Purshad) ought to worship it. A terrace was then made at the same place where the stone had fallen, and it was put on it. On Monday morning when I saw it, it was of a kunkur colour. The more it was worshipped the more it became black."

ADDITIONS TO THE MUSEUM.

FROM 1ST JULY TO 30TH SEPTEMBER 1885.

Five specimens of Eozoon Canadense, from Sir William Dawson, Montreal.
PRESENTED BY H. E. THE COUNTESS OF DUFFERIN.

A sample of fire clay from Mangrup, Meywar, Rajputana.
PRESENTED BY COLONEL C. K. M. WALTER, RESIDENT, MEYWAR.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1885.

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ASHBURNER, *Charles A.*—Brief description of the Anthracite Coal-fields of Pennsylvania, 8° Pam. Philadelphia, 1884. THE AUTHOR.

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VOLUME XIX.

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PART 4.

ERRATA.

Page 74, insert '*none in*' at beginning of line 2 (in some copies).
" 119, line 17, for *rocks* read *cracks*.
" 121, a terminal *h* has got in by mistake in 3 words.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 1.] 1886. [February.

Annual Report of the Geological Survey of India, and of the Geological Museum, Calcutta, for the year 1885.

A discovery of great interest to Indian geology was made in the year under review; and it affords as striking an instance as could be quoted of the magic light that can be thrown upon stratigraphical puzzles by a simple find of fossils. We owe the discovery to Dr. H. Warth, who was some time ago in charge of the great Mayo salt mines at Khewra, in the midst of the most interesting geological sections in India; and he then contributed not a little to our knowledge through his intelligent zeal in collecting fossils, as the students of Dr. Waagen's description of the Salt-range fossils in the Palæontologia Indica cannot fail to notice. Dr. Warth has again lately been deputed on other duty in the same neighbourhood, and his industry in the cause of geology has now met with signal reward. In February last I received from him a small box of fossils, of which he wrote—" Besides these fragments you will find in the tin box a broken pebble wrapped in green paper. You will notice that the pebble contains a fossil. The pebble was found at Choya Saidan Shah, loose amongst other pebbles which had weathered out of the pebble bed or cretaceous (?) conglomerate to which Wynne refers at page 104 of his Salt-range Memoir. The pebbles and boulders consist usually of crystalline rocks, but it appears that there are also fossiliferous rock pebbles amougst them. In case you can get this fossil determined I would thank you for letting me know the result." The fossil was very distinctly a *Conularia*, which is, according to the books, of middle or lower palæozoic age; but I sent it by next post to Dr. Waagen, whose first impression regarding it was given in a letter dated 25th of March: " The fossil you sent me is really a *Conularia* and comes probably from silurian strata, being carried down from the Himalayas either by ice action or by floods, during upper cretaceous times." Having no preconceptions against the occurrence of silurian deposits in the Salt-range itself, I could not for

a moment concur as to the derivation suggested; and Dr. Warth's further pursuit of this exciting clue soon determined that the so-called pebbles are *in situ*, their form being concretionary and not due to water wear. A large collection of these and a few other associated fossils were sent by him to Dr. Waagen, and form the material of his very interesting paper in the current number of the Records. The boulder bed hitherto placed, not without misgivings (for the similarity of the boulder beds throughout the range has always been noticed), with the cretaceous olive-series at the east end of the Salt-range, being thus proved to be palæozoic, its affiliation with the boulder beds beneath Dr. Waagen's Productus-limestone became at once an obvious necessity. Dr. Waagen seems inclined still to include this zone in his Productus-limestone series; but with such marked unconformity, and the distinct facies of the small fauna now described, the proceeding would seem somewhat to strain the practice usual in such matters. Still more difficult will it now appear to retain the Neobolus-beds of the east Salt-range as a member of the Productus-limestone series. The emendation proposed by Dr. Waagen (at page 3 of his Salt-range fossils) of Mr. Wynne's rough classification of these deposits will probably have to be reconsidered. In the connection presently to be noticed, the name 'Productus-limestone' chosen by Dr. Waagen for the upper palæozoic series of the Salt-range promises to be confusing, for the rock elsewhere *underlying* the supposed equivalents of the Talchirs is sometimes quoted as a Productus-limestone.

The important corrections made in the stratigraphy of the Salt-range by this find of fossils are perhaps of less interest themselves than is their bearing upon the correlations of our Indian Gondwana rock system; and this inference is almost as obvious as the primary one. A single great glacial boulder deposit of palæozoic age, and distinctively of southern derivation, being established in the Salt-range, it was impossible not to conjecture its identification with the Talchir glacial deposits found almost everywhere at the base of the Gondwana rocks of peninsular India. Ever since the origin of the Survey the correlation of the great isolated plant-bearing series, for which I proposed the name Gondwana under which it is now known, has been an object of inquiry and contention. The correspondence of some of these fossil plants with those associated with oolitic marine fossils in Cutch as previously described by Captain Grant was recognised from the first; and the more exact correlation on that side was established by Dr. Feistmantel's identifying the flora of the topmost (Jabalpur) group of the Gondwana sequence with the Umia horizon (top jurassic) of Cutch. The lower Gondwana or Damuda flora is not represented in Cutch, and for it the nearest known standard of comparison was in Australia, where some coal-beds with a flora more or less resembling that of the Damuda series are distinctly interstratified with beds containing a marine fauna of well-marked lower-carboniferous facies. This very strong evidence was accepted by Dr. Oldham as presumptive proof of the palæozoic age of the Damuda formation; and he went a little further in endeavouring to show that the Damuda flora itself might be reconciled to the palæozoic type. This view was strongly contested by the palæo-botanists, who on their side endeavoured to discredit the stratigraphical facts of continuous sequence and interstratification. Thus both parties, actuated

by the same presumption of an assumed necessary correspondence between two distinct lines of palæontological evidence, committed the mistake of doing violence to fact. It need hardly be said that fact has proved the stronger: the facts on both sides remain fast, while only the preconception has to make way for a fact of a higher order. Dr. Feistmantel established to the satisfaction of competent judges that the Damuda (including the Talchir) flora is distinctively mesozoic: and the compromise with which he supposed the controversy would be closed[1] was, the provisional identification of the Bacchus-Marsh glacial boulder bed of Victoria (which he had fairly identified with the Talchir boulder bed of India) with the Haukesbury horizon of the New South Wales sequence, thus putting out of court the obnoxious interstratification, which occurs well below the Haukesbury beds. But now comes the announcement of the identification of the Talchirs with a well-established carboniferous glacial boulder bed within the borders of India itself. Of course it is so far open to deny the identification, and to assume two widely distinct glacial periods in the Indian region, for the Salt-range is several hundred miles distant from the nearest known appearance of Talchirs, and no fossils common to both have been found. This stand would probably be made but for the strange coincidence that the same view has arisen contemporaneously from a wholly independent quarter.

During the past summer Mr. R. D. Oldham took privilege leave for a trip to Australia and obtained two months' extension on duty, to enable him to see something of the Gondwana rocks of that region. The result of his observations is published in the current number of the Records. His paper reached me within the same week as Dr. Waagen's, each writer being wholly unaware of what the other was about. The case is stated very clearly, and it is a strong one, and far more natural-like than the compromise proposed by Dr. Feistmantel. Mr. Oldham of course reaffirms the distinct interstratification of the Newcastle and Stony Creek coal-beds of Gondwana affinities, with the marine palæozoics, a point that no observer has questioned. But with and beneath these he calls attention to glacial boulder deposits that represent the similar beds of Bacchus-Marsh far more adequately than does anything of that kind found in the Haukesbury beds. This is of course a point for Australian geologists to work out. Meanwhile the verisimilitude of the combined evidence would seem conclusive in favour of the original view of the palæozoic age of the lower Gondwana deposits, as continuously contended for by Dr. Blanford, who made the original descriptions of the lower Gondwana groups from his surveys of the Raniganj and Talchir coal-fields. The general interest of this determination is very great: it would be, so far as I know, the first clear and broad case to confirm the assertion made twenty-five years ago by Professor Huxley when introducing the term 'homotaxis'; for it shows that a full-blown mesozoic flora in one region of the earth was contemporaneous with a full-blown palæozoic flora in another region. It is the point for which Dr. Blanford made out so good a case in his address to the Geological Section of the British Asociation at Montreal in 1884; but it is a great step from argument to conclusive proof. Had the workers on both sides duly profited by Professor Huxley's warning, the preconceptions that have so distracted our understanding should not

[1] Pal. Ind., Gondwana Flora, vol. III, part 2, pp. 130-32.

have arisen. There is however no occasion to discredit palæo-botanical evidence; it bears a full share of credit in the result that has been attained.

In developing the inferences to be drawn from the correlation of the Talchir with the Salt-range boulder beds, Dr. Waagen has overlooked the fact that Mr. Oldham gave a very circumstantial discussion of what is substantially the same problem in his paper published in the Journal of the Asiatic Society of Bengal for 1884 (duly noticed in my last Annual Report) on the Talchir glacial period as embracing Australia and South Africa. Mr. Oldham has now himself brought the best evidence for the small correction in time that makes the two positions identical. In connection with these speculations I would venture with diffidence to mention a possible objection that has occurred to me regarding the great liberty taken in raising and sinking continents at discretion. The argument upon which these performances depend requires in some form the doctrine of specific centres: has that survival of old times been duly modified in accordance with principles now accepted? Can it with any plausibility be asserted that under similar trains of conditions, such as may reasonably be supposed to have occurred in distantly separated parts of the earth, forms within the loose limits of specific identity might not arise from wholly distinct stocks? The dogma of biogenesis is similarly implicated as an occult influence in such questions, its operation being inscrutable; so far its appropriate service (*qua* dogma) has been as a fresh quicksand for discomfited theologians to build castles upon.

CHHATTISGARH.
Dr. King.

The work in Chhattisgarh includes two distinct geological areas; the Vindhyan basin of the upper Mahanadi, and the chain of Gondwana rocks, with coal measures, passing along its north-east border from Sambulpur into connection with the Rewah basin. Cursory traverses of this ground were made some time ago by Mr. Blanford, Mr. Ball, and myself; and a portion of the coal-fields was mapped by Mr. Ball. The Vindhyans are for the most part quite flat, forming the open plains of Chhattisgarh; but along the west boundary there is some obscurity regarding their relation to the rocks forming the Saletekri hills. When I traversed these rocks in 1866, it seemed to me that the Vindhyans of the plains partook in the disturbance and were at least partly represented in the hill rocks in the Chilpi Ghat section, and that all the rocks there were of the same family, in the same way as occurs among the Vindhyan groups of the Karnul-Kadapah basin. The progress made in this investigation is well elucidated in Dr. King's report, published (with a map) in the Records for last November.

Among the Gondwana rocks, Dr. King was chiefly engaged in directing the practical exploration of the Rampur coal-field, which is the southern portion of the Raigarh and Hingir basin formerly surveyed by Mr. Ball (in 1876). This ground was selected as being nearest to the proposed line of railway. The sites for borings selected by Dr. King were well placed, for the coal was struck as expected, but unfortunately its quality has proved uniformly bad. Samples taken at every foot of each seam were carefully assayed in the Survey laboratory, but the proportion of ash in the samples ranged from 27 to 44 per cent., 23 per cent. being the lowest amount in any partial sample. Mr. Stewart, the Assistant Mining Engineer in immediate charge of the borings, has had much experi-

ence in the work, formerly in the Satpura basin and lately under Mr. Hughes in South Rewa; so there is every ground for confidence in the care exercised. The same disappointing results have continued up to date; so Dr. King is arranging to move the boring operations to a new field, though unavoidably less favourably placed with reference to the line of railway as now projected.

Dr. King reports with satisfaction of the work done by Sub-Assistant Hira Lal in tracing simple boundaries.

Mr. Bose.

Mr. Bose made a wide traverse of the Vindhyans to the south and south-west. The defects brought to notice by his previous season's work are not such as can be quickly rectified; he still displays a very inadequate conception of the detailed study of rocks in the field. He is now working under the immediate direction of Dr. King.

SOUTH INDIA.
Mr. Foote.

During the season 1884-85, Mr. Foote was able to take up his survey in the Bellary District, from which he had been called away in the previous season to search for coal in the gneiss of Hyderabad. The Sandur hills, to the west of Bellary, were the principal object of investigation; they are formed by one of the bands of transition rocks that traverse the peninsula more or less continuously with a north-northwesterly trend, and are all remnants of a once wide-spread formation which Mr. Foote now unites and distinguishes as the Dharwar series, as shown to be unconformable to the gneiss, with which it has been intimately associatad by complete folding together. In the Sandur hills they contain masses of rich hæmatite.

Wadjra Karur diamond field.

Mr. Foote made a careful examination of the well-known diamond field at Wadjra Karur to which special interest has lately been attracted on account of the mining operations started there by Messrs. Orr & Sons of Madras. The mother-rock of the diamond has of course been an object of special search, but hitherto without avail in India, for in the oldest rocks in which this gem is found, the gravel-stones at the base of the upper-Vindhyans, it is only a transported pebble like the rest of its associates. It seemed as if at last the original matrix had been found at Wadjra Karur in a 'pipe' or 'neck' of a peculiar tuff-like trappean rock observed there by an explorer from South Africa, who declared this rock to be identical with the famous diamond matrix of Kimberley. It was upon this very tempting inducement that the works in question were started; but as yet no speck of the gem has rewarded the endeavour. Mr. Foote says that the rock is quite unique in his extensive experience in South India, and is completely isolated in the surrounding epidotic granite gneiss. The position is within a few miles to the west of the Kadapa-Karnul Vindhyan basin in which diamonds are extracted from the Banaganpilly sandstone, and Mr. Foote sought diligently for any outlying remnant of that rock in the neighbourhood of Wadjra Karur, but there certainly is none now recognisable, though of course this would not preclude such an origin for the local debris. It is difficult however to relinquish hope in the otherwise extraordinary coincidence of the occurrence of so peculiar a rock where diamonds have certainly been found in considerable number and of unusual size.

In the Bellary district Mr. Foote was within visiting reach of the Billa Surgam caves in Karnul where his son, Lieutenant Foote, R.A., was carrying on explorations under his direction. At the close of the season the spoils were taken to Madras and carefully sorted—a work of no small labour seeing that the registered specimens amounted to some 4,700. A notice of the excavations made, with an abstract of the results, was published in the Records for November last. The exploration was extensive and thorough, and it must be said that the expectations, which chiefly related to pre-historic human remains, have been so far disappointed. The collections have now been despatched to Mr. Lydekker for examination, and for description so far as may be desirable. Further exploration may fairly be postponed till the result is known. A reason for this partial failure may perhaps be suggested in the fact that these caves seem to be and to have always been dripping and even water-channels in the wet season, whereas it is only in caves suited for shelter and even residence that more perfect remains of man or other animals may be expected to occur.

The Caves.

Mr. Hacket returned from furlough towards the end of November 1884, and got into camp at Palampur on the 5th December. He covered a large area (some 3,000 square miles) of new ground in Meywar, in continuation of his previous work to the north. It is entirely composed of the same obscure rocks—the schists, limestones and quartzites of the Arvali system in transitional relation with gneiss and granite masses. Mount Abu is a mass of coarse highly felspathic gneiss. It will need much time and labour to unravel the normal sequence of these very intricate formations.

RAJPUTANA: *Mr. Hacket.*

Mr. Griesbach contributed to the February number of the Records a small instalment of his observations with the Afghan Boundary Commission. The southern route taken to Herat crossed the continuations of the tertiary and cretaceous formations previously described by him at and west of Kandahar (Memoirs, XVIII, 1), the hippuritic limestone being very prominent, with copious intrusions of basic trap and syenitic granite. In the axial range of the Siah Koh and Doshakh south of the Herat valley, palæozoic rocks make their first appearance, as represented by a carboniferous Productus-limestone, dipping northwards towards the Hari Rud valley. The Paropamisus range, north of the valley, seems to be largely made up of a great plant-bearing series which Mr. Griesbach provisionally parallels with the Indian Gondwana system, conjecturing that it overlies the carboniferous Productus-limestone. In notes of a year's later date, in the current number of the Records, Mr. Griesbach adheres to this general rock sequence, and describes its distribution in the Binalat and other ranges of eastern Khorasan.

Mr. Griesbach.

The result of Mr. Oldham's observations in the Andamans is published with a map in the Records for last August. It gives the classification and distribution of the rocks so far as he was able to see them, with a digest of all previous explorations. The opportunity afforded by the Topographical Survey operations can only be said to have been better than nothing; when every move could only be as suited a totally different object, there was no possibility of continuous geological observations

THE ANDAMANS: *Mr. Oldham.*

During the current season Mr. Oldham is making a tour through the geologically unexplored desert region of north-western Rajputana, and will resume his Himalayan work in the spring. In a letter just received from him, dated the 28th January, he makes an announcement of great interest relating to the discussions noticed above. Referring to the boulder beds of Lowo mentioned by Mr. Blanford in his paper on the Indian Desert between Sind and Rajputana (Records, vol. X, p. 16), Mr. Oldham finds them spreading over a large area, and says—" they are certainly post-Vindhyan and at the base of the series which runs up into the jurassics, so can hardly but be Talchir.

NORTH-EAST FRONTIER: *Mr. LaTouche,*

Mr. LaTouche was again (at my request) diverted from his appointed work in the Garo Hills to take advantage of the topographical exploration party to the head waters of the Dehing on the extreme east frontier of Assam. As everywhere in that region, the conditions are very unfavourable for geological observations, on account of the dense vegetation. It has however been ascertained that the whole upper valley of the Dehing is occupied by tertiary deposits, chiefly sandstones, while the actual crest of the ridges to north and east are of crystalline rocks; whether any small outcrop of older strata intervened, could not be made out. By an unfortunate error of judgment we have been deprived of what might have more than compensated for the interruption of our regular work: a small detachment of the party crossed the watershed, and made some days' march to the north-west branch of the Irawadi; the two officers who went on this trip were in the same line of work, and the only man of the party whose eyes were something more than optical instruments was left behind. It would be more to the credit of the service and for the public advantage if on such occasions petty considerations of seniority were laid aside.

THE PENCH COAL-FIELD. *Mr Jones.*

Mr. Jones did a good season's work in mapping the whole area hitherto known as the Pench coal-field and for some distance to the west in the direction of the Shahpur coal-field on the same (south) side of the Satpura Gondwana basin. He has added several new outcrops of coal to those marked many years ago by Mr. Blanford and Major Ashburner. There seemed at first an intention on the part of the Chief Commissioner of the Central Provinces to take advantage of Mr. Jones' presence to have the measures tested by trial borings, but the old difficulty regarding this field has again prevailed: it is too remote and inaccessible for a special coal line in either direction to be remunerative, and the authorities consider that as a through-line it would not lead to any important traffic.

THE KASHMIR EARTHQUAKE.

The earthquake in Kashmir occurred just at the close of the field season and Mr. Jones was deputed to report upon it. The same cause that made it so disastrous in respect of loss of life—the mode of construction of the native houses, whereby the heavy earthen roofs simply collapsed between the crumbling walls—left little opportunity for critical observation of direction. Mr. Jones' report, in the Records for November, seems to make the most of what facts he could collect. It was especially unfortunate that Sir Oliver St. John was laid up with illness during the time of Mr. Jones' visit, thus depriving him of invaluable assistance in gaining

information. Sir Oliver considers that the distribution of maximum ruin would indicate for the focus a position more to the north-west than that assigned by Mr. Jones.

THE KUMAUN HIMALAYA: *Mr. Middlemiss.*

During last season Mr. Middlemiss had the north-west Himalaya all to himself, and he was very near making another distinguished mark in the year's calendar by an important find of fossils. Even more than peninsular India, the Lower Himalayan region has ever been a perplexity to us for want of fossil guidance. The few obscure fossils found by myself in 1861 in the Tal river section, at the east end of the Dehra Dun, have remained ever since the only known organic remains older than nummulitic south of the snowy range, although repeated search has been made by expert geologists and others. Some miles to the east of the Tal, but in the same set of beds, Mr. Middlemiss collected a more numerous and somewhat better set of fossils, and with laudable enthusiasm he made an attempt to recognise their facies and to assign a horizon for them, as was announced in the Records for May last. When brought down to Calcutta we were unable to confirm the opinion passed upon them, and as we are most unfortunately at present without a palæontologist, the whole were sent to Dr. Waagen with much hope that he would give us a clue. In this we were disappointed; even this high authority can only say of them that the facies seems rather mesozoic than palæozoic, thus at least partially confirming Mr. Middlemiss' diagnosis. The prospect has however been brightened by this discovery; Mr. Middlemiss has traced these beds over a considerable area in Kumaun and they must ere long yield something intelligible.

In a letter (dated 28th January) just received from Mr. Middlemiss he announces an important correction in the position he had assigned for these fossiliferous beds of the Tal. In the sections described by him in May last the fossiliferous group seemed to underlie the massive limestone of the overhanging ridge. He has recently found clear sections in the gorge of the Ganges showing that the normal position of the Tal group is above the massive limestone, and there next below the nummulitic band.

THE BENGAL EARTHQUAKE.

The Bengal earthquake also happened conveniently during the recess from field work, and Mr. Middlemiss was entrusted with the investigation. He was fortunate in securing tolerably good observations in positions favourable for ascertaining the focus of the shock.

Publications.—Two Memoirs were published during the year, being Mr. Hughes' report on the southern coal-fields of the Rewah Gondwana basin, with a large map of this very extensive area, and several small maps of some special coal-fields, forming part 3 of volume XXI; and part 4 of the same volume, being Mr. Mallet's description of the volcanoes of Barren Island and Narcondam.

The Records for the year, being volume XVIII of the series, contain twenty-nine articles of various interest on current work relating to the geology of India.

Although we are still deprived of the services of a palæontologist in India whereby much inconvenience and delay has been caused both in our field work and in the museum, the publication of the *Palæontologia Indica* has made fair progress during the year, thanks to the special arrangements made for this most

important work, and to the generous co-operation of palæontologists. Of series XIV, fasciculus 5 of part 3, describing the fossil Echinoidea from the Gáj or miocene series of Sind, was brought out during the year by Professor Martin Duncan and Mr. Percy Sladen. The concluding part of this volume is now in the press.

Of Dr. Waagen's work on the Salt-range fossils there were issued fasciculus 5 of part 4, concluding the Brachiopoda, and part 5, containing the Bryozoa, Annelida and Echinodermata of the Productus-limestone series. The plates and manuscript for the concluding part of the Productus-limestone series are well advanced; and Dr. Waagen informs me that good work has been done in preparing the material for the second division of the Salt-range fossils series—the Ceratite beds.

Mr. Lydekker has been very diligent with his division of our work. Of series XV, Indian Pretertiary Vertebrata, he brought out during the year part 4, on the Labyrinthodont, from the Bijori group; and part 5, the Reptilia and Amphibia of the Maleri and Denwa groups, concluding volume I of this series; also part 6, the Siwalik and Narbada Chelonia, of series X, devoted to Indian Tertiary and Post-tertiary Vertebrata. He has a troublesome job before him in the numerous collections of bone fragments from the Karnul caves; but a very large proportion of them are probably unfit for specific or even generic identification, Mr. Foote seems to have been so ultra-scrupulous in preserving every fragment that turned up.

Museum.—The collections are steadily increasing in value by the return of the type specimens described in the Palæontologia. Mr. Blyth has amply justified the appointment of a museum assistant; with this help it has been possible to get all the collections into something like thorough order. He has also been very useful to Mr. Mallet in the laboratory. Contributions to the museum are notified quarterly in the Records. Mr. Wood-Mason has recently presented some interesting fossils collected by himself in the Raniganj coal-measures and described by Dr. Feistmantel in the Journal of the Asiatic Society of Bengal.

Library.—There were 1,762 volumes or parts of volumes added to the library during the year; 978 by presentation and 784 by purchase.

Personnel.—Mr. Hughes was throughout the year on detached duty, in charge of the new colliery operations at Umaria. Mr. Fedden was absent on furlough for the whole year. Sub-Assistant Kishen Singh also took furlough for a year. The failure of our permanent palæontologist, as above mentiond, was owing to Dr. Fiestmantel having accepted a professorship at Prague and resigned his appointment on the Indian Survey at the termination of his two years' furlough. We are at least fortunate in the period at which this disappointment has occurred; in his three volumes on the Gondwana Flora he has cleared up many difficulties connected with the principal rock system of India, and given us a standard for future work in that branch of palæontology.

H. B. MEDLICOTT,

Director of the Geological Survey of India.

CALCUTTA,

The 31st January 1886.

List of Societies and other Institutions from which Publications have been received in donation or exchange for the Library of the Geological Survey of India, during the year 1885.

BATAVIA.—Batavian Society of Arts and Sciences.
BELFAST.—Natural History and Philosophical Society.
BERLIN.—German Geological Society.
„ Royal Prussian Academy of Science.
BOLOGNA.—Academy of Sciences.
BOMBAY.—Bombay Branch, Royal Asiatic Society.
„ Meteorological Department.
BOSTON.—American Academy of Arts and Sciences.
„ Society of Natural History.
„ State Library of Massachusetts.
BRESLAU.—Silesian Society.
BRISBANE.—Royal Society of Queensland.
BRISTOL.—Bristol Museum and Library.
„ Bristol Naturalists' Society.
BRUSSELS.—Royal Academy of Belgium.
„ Royal Geographical Society of Belgium.
„ Royal Malacological Society of Belgium.
„ Royal Natural History Museum of Belgium.
BUDAPEST.—Hungarian Geological Society.
„ Hungarian National Museum.
„ Royal Geological Institute, Hungary.
BUENOS AIRES.—National Academy of Sciences, Cordoba.
CALCUTTA.—Agricultural and Horticultural Society.
„ Asiatic Society of Bengal.
„ Meteorological Department, Government of India.
„ Presidency College.
„ Survey of India.
„ The Calcutta University.
CAMBRIDGE.—Cambridge University.
„ Philosophical Society.
CAMBRIDGE, MASS.—Museum of Comparative Zoology.
CHRISTIANIA.—Editorial Committee, Norwegian North Atlantic Expedition.
„ Norwegische Comm. der Europäischen Gradmessung.
CINCINNATI.—Society of Natural History.
COPENHAGEN.—Royal Danish Academy.
DAVENPORT.—Academy of Natural Sciences.
DELFT.—Polytechnic School.
DENVER.—Colorado Scientific Society.
DRESDEN.—Isis Society.
DUBLIN.—Royal Dublin Society.
EDINBURGH.—Geological Society.

EDINBURGH.—Royal Scottish Society of Arts.
" Scottish Geographical Society.
GENEVA.—Physical and Natural History Society.
GLASGOW.—Geological Society.
Glasgow University.
Philosophical Society.
GÖTTINGEN.—Royal Society.
HALLE.—Leopoldino Academy.
" Natural History Society.
HAMILTON, CANADA.—The Hamilton Association.
HARRISBURG.—Second Geological Survey of Pennsylvania.
HOBART.—Royal Society of Tasmania.
KÖNIGSBERG.—Physikalisch-Ökonomische Gesellschaft.
LAUSANNE.—Vaudois Society of Natural Sciences.
LIÉGE.—Geological Society of Belgium.
LISBON.—Geological Survey of Portugal.
LIVERPOOL.—Geological Society.
Literary and Philosophical Society.
LONDON.—British Museum.
Geological Society.
Iron and Steel Institute.
Linnean Society.
Royal Asiatic Society of Great Britain and Ireland.
Royal Geographical Society.
Royal Institute of Great Britain.
Royal Society.
Society of Arts.
The Editor of the "Journal of Science."
Zoological Society.
MADRAS.—Agricultural Department.
Madras Observatory.
Meteorological Department.
MADRID.—Geographical Society.
MANCHESTER.—Geological Society.
MELBOURNE.—Department of Mines and Water-supply, Victoria.
" Royal Society of Victoria.
MILAN.—Royal Institute of Science, Lombardy.
MINNEAPOLIS.—Minnesota Academy of Natural Science.
MONTREAL.—Geological and Natural History Survey of Canada.
MOSCOW.—Imperial Society of Naturalists.
MUNICH.—Royal Bavarian Academy.
NEUCHATEL.—Society of Natural Sciences.
NEWCASTLE-ON-TYNE.—North of England Institute of Mining and Mechanical Engineers.
NEW HAVEN.—Connecticut Academy of Arts and Sciences.
The Editors of the "American Journal of Science."

PARIS.—Geographical Society.
„ Geological Society of France.
„ Mining Department.
PENZANCE.—Royal Geological Society of Cornwall.
PHILADELPHIA.—Academy of Natural Sciences.
„ American Philosophical Society.
„ Franklin Institute.
PISA.—Society of Natural Sciences, Tuscany.
RIO DE JANEIRO.—School of Mines.
ROME.—Royal Geological Commission of Italy.
ROORKEE.—Thomason College of Civil Engineering.
SACRAMENTO.—California State Mining Bureau.
ST. PETERSBURG.—Geological Commission of the Russian Empire.
„ Imperial Academy of Sciences.
SALEM, MASS.—American Association for the Advancement of Science.
„ Essex Institute.
„ Peabody Academy.
SAN FRANCISCO.—California Academy of Sciences.
SHANGHAI.—North China Branch, Royal Asiatic Society.
SINGAPORE.—Straits Branch, Royal Asiatic Society.
STOCKHOLM.—Geological Survey of Sweden.
„ Royal Swedish Academy.
STRASBURG.—Royal University.
SYDNEY.—Australian Museum.
„ Department of Mines, New South Wales.
„ Royal Society of New South Wales.
•TOKIO.—Seismological Society of Japan.
TORONTO.—Canadian Institute.
TURIN.—Royal Academy of Sciences.
VIENNA.—Imperial Academy of Sciences.
„ Imperial Geological Institute.
WASHINGTON.—Commissioner of Agriculture.
„ Department of the Interior.
„ National Academy of Sciences.
„ Smithsonian Institute.
„ United States Geological Survey.
WELLINGTON.—Geological Survey of New Zealand.
„ New Zealand Institute.
YOKOHAMA.—Asiatic Society of Japan.
„ German Naturalists' Society.
YORK.—Yorkshire Philosophical Society.
ZÜRICH.—Natural History Society.

The Secretary of State for India.

The Governments of Bengal, Bombay, Madras, North-Western Provinces and Oudh, and the Punjab.

Chief Commissioners of Assam, British Burma, and Central Provinces.

The Commissioner of Northern India Salt Revenue.

The Resident at Hyderabad.

The Superintendent of Government Printing, India.

Departments of Finance and Commerce, Foreign, Home, and Revenue and Agriculture.

Report *on the* International Geological Congress *of* Berlin *by* W. T. BLANFORD, LL.D., F.R.S.

The third International Geological Congress, postponed in 1884 on account of the prevalence of cholera in Southern Europe, has now been held in Berlin in the week commencing on the 27th September last. Acting upon instructions received from the Government, at the desire of the Director of the Geological Survey of India, I attended this congress, like that of Bologna in 1881, as the representative of the Indian Geological Survey. The following brief account of the proceedings and results of the Berlin Congress is similar to that which I wrote on the previous occasion, and which was published in the Records of the Geological Survey of India for 1882, Vol. XV, page 64.

The meeting at Berlin was held in the Reichstagsgebäude (House of the Imperial Parliament), in the hall in which the German House of Representatives meet. Council and committee meetings were in adjoining rooms. A collection of maps and geological specimens, many of which were of great interest, was exhibited at the Bergakademie (Mining School).

The attendance of geologists was considerably larger than at Bologna,[1] amounting altogether to 255, of whom 163 came from Germany, 16 from Austria-Hungary, 18 from Italy, 11 from Great Britain, 10 from France, 9 from the United States, 6 from Russia, the same number from Belgium, and smaller numbers from other countries. Asia was represented by one member from Japan and one from India. Amongst those who were present were nearly all the principal geologists of Germany, and the representation of other countries was both large and important.

The arrangements as to the Bureau (council or general committee) and the selection of vice-presidents, secretaries, &c., were similar to those of Bologna. The president was Professor E. Beyrich, and the general secretary, Mr. W. Hauchecorne. These two geologists, it may be mentioned, are the directors of the new geological map of Europe, by far the greater share of the work upon which has been undertaken by them. The honorary president, Professor H. von Dechen of Bonn, who attended the meeting throughout, belongs to the generation of geologists who were contemporaries with Lyell and Murchison.[2] It would be difficult to name any one more generally respected throughout the scientific world. Professor G. Capellini, the able president of the Bologna Congress, also attended the meeting

[1] The number actually present at Bologna was 225, of whom 150 were from Italy.

[2] His election as foreign member of the Geological Society of London dated from 1827, or 24 years before the date of election of any other foreign member now living.

In one important point the last congress differed from that which preceded it. The whole of the time at Bologna was devoted to the discussion of questions relating to nomenclature, geological and palæontological, or to map colouration. At Berlin only a portion of each sitting was occupied with similar discussions, the remainder being reserved for papers on various geological subjects and contributed by writers from several different countries. These papers will, it is understood, be published in the volume containing the results of the meeting. It is a question whether several of these papers—perhaps the majority—were not better adapted for meetings of scientific societies than for presentation to a body of geologists drawn from various nations. Some, indeed, irrespective of the subjects treated, were scarcely of sufficient importance to deserve international attention. On the other hand, the time devoted in the discussion of questions of the highest importance was utterly insufficient, and such matters as the classification of tertiary rocks and even the number of tertiary systems were not considered at all.

Arrangements at close of Bologna Congress.—In order to understand the proceedings at Berlin, it is necessary to refer to the arrangements made at the close of the Bologna meeting. The principal objects of that congress were to agree upon a system of geological nomenclature, to define a scale of colours for geological maps, and to formulate laws for the regulation of palæontological nomenclature. All of these projects were partially carried out. The terms to be applied to the principal kinds of divisions under which it was proposed to classify sedimentary rocks were noted, and designations approved for the corresponding divisions of geological time. The colours for tertiary, cretaceous, jurassic and triassic beds, and for crystalline schists, were accepted, those for palæozoic systems being referred to a committee appointed to arrange for the publication of a geological map of Europe. Some simple rules for palæontological nomenclature were also discussed and approved by a majority.

In addition to the progress made in coming to an agreement upon the various propositions laid before the congress, it was resolved to appoint a committee for the preparation and publication of a geological map of Europe on the scale of 1 : 1,500,000 (23·67 miles to an inch), and to this committee were referred for further consideration various details connected with colouration, such as the tints to be adopted for palæozoic rocks, as already mentioned. Another and larger committee was appointed to carry on further the attempt at rendering geological nomenclature uniform.

International committee meetings in 1882 and 1883.—Meetings of both these committees were held simultaneously at Foix (Southern France) in September 1882, and at Zurich, in Switzerland, in August 1883. Both meetings were very fairly attended, and I was able to be present on both occasions. The proceedings at Foix were for the most part preliminary, and it was chiefly at Zürich that the actual discussion on nomenclature took place.

Meantime considerable progress was made with the topography of the new geological map of Europe, and a complete scheme of geological colours was proposed at Foix. It will be necessary to revert to this subject because several of the decisions of the congress at Berlin refer to this map, and consequently have not the same scope as the decisions of the Bologna meeting.

The most important question in geological classification,—more important than the definition of such terms as group, system, era, period, &c.,—is the formation of a geological time scale, by which to compare the sedimentary formations of different countries. Up to a certain point there is a fairly general agreement. Nearly all geologists consent to a sub-division of sedimentary rocks into palæozoic, mesozoic, and cænozoic or tertiary; and several of the systems and even the series into which each of these groups is divided are also generally recognized; but there are some sub-divisions, such as the so-called Quaternary, the Permian and Rhætic, the rank or the affinities of which, or both, are far from being definitely fixed.

The discussion at Zürich was chiefly directed to the determination of the systems into which the greater groups should be divided. The divisions proposed at Foix for the map of Europe by a committee of German and Austrian geologists[1] assembled for the purpose were the following :—

1. Gneiss and Protogine.
2. Crystalline Schists.
3. Phyllites (azoic slates, &c.).
4. Cambrian.
5. Lower Silurian.
6. Upper Silurian.
7. Lower Devonian.
8. Middle Devonian.
9. Upper Devonian.
10. Lower Carboniferous (mountain-limestone, &c.).
11. Upper Carboniferous (coal-measures, millstone-grit, &c.).
12. Lower Permian (Rothliegendes).
13. Upper Permian (Zechstein, &c.).
14. Lower Trias (Bunter).
15. Middle Trias (Muschelkalk).
16. Upper Trias (Keuper).
16½. Rhætic (*provisionally*).
17. Lower Jurassic (Lias).
18. Middle Jurassic (Dogger, including the Callovian).
19. Upper Jurassic (Malm with Tithonian and Purbeck).
20. Lower Cretaceous.
20½. Gault (*provisionally*).
21. Upper Cretaceous.
22. Eocene.
22½. Flysch (*provisionally*).
23. Oligocene (with Aquitanian).
24. Miocene.
25. Pliocene.
26. Diluvium (Pleistocene).
27. Alluvium.

Rhætic, Gault, and Flysch were merely inserted as provisional terms.

Before the meeting of the committees at Zürich, a circular was sent by the president, Professor Capellini, pointing out that there were seven questions of

[1] Including Professors Von Dechen, Gümbel, Von Hauer, F. Roemer, and H. Credner, besides Professor Beyrich and Mr. Hauchecorne.

particular interest requiring solution, in order that the geological classification to be employed in the map of Europe should be determined. These questions were—

1. Do you approve for the index to the map of Europe of the 27 stratigraphical divisions mentioned on page 8 of the Record (*compte rendu)* of the Foix proceedings, or do you wish for any modifications, and what are they?
2. Are you of opinion that the Rhætic should be united to the Lias or to the Trias?
3. Should the Gault be joined to the lower or to the upper Cretaceous?
4. Should the *Flysch* be united to the Eocene or to the Oligocene?
5. The congress not having yet determined the conventional colours for palæozoic periods, do you approve of the following proposed by the directors of the map?

   Cambrian, reddish grey.
   Lower Silurian, dark sage-green[1] (vert-soie).
   Upper Silurian, pale ,,
   Lower Devonian, dark-greenish brown.
   Middle Devonian, medium ,,
   Upper Devonian, pale ,,
   Lower Carboniferous, bluish grey.
   Upper Carboniferous, grey.
   Lower Permian, burnt sienna.
   Upper Permian, sepia.

6. Be so good as to propose a term as the chronological equivalent of *assise,* to represent from this point of view, divisions of the fifth order.
7. Would you recommend that the terms *group* and *series* should be interchanged, as was proposed at Foix; that divisions of the first order should be called series, and those of the third order groups?

To these questions replies were sent by a few national committees. Questions 2, 3, and 4 are really part of question 1, and they were discussed at Zürich before the others.

On the subject of the Rhætic opinions were greatly divided. In France and England the Infra-lias, *Avicula contorta* or Penarth beds are so intimately connected with the Lias that for a long time they were classed as a part of it. In the Eastern Alps on the other hand, as in the Himalayas, the Rhætic beds are much more developed and form the uppermost portion of the Triassic system. Lastly, in Franconia the Rhætic beds are actually intercalated in the uppermost clays of the Keuper. A compromise was finally adopted for the map of Europe, the Rhætic being represented by coloured cross-lines applied either to the Triassic or Jurassic colour, according to what was considered correct in different localities.

[1] Mr. Blanford did not translate *vert-soie,* and I cannot find the term in any available authority, living or printed. Mr. T. Wardle, an expert in the technology both of colours and of silk, has given me 'sage-green' as the nearest term for the silurian colour in the 'Gamme des couleurs' issued by the international map committee, and this is presumably the *vert-soie* of the text.—H. B. M.

The union of the Gault with the upper or the lower Cretaceous was also a matter on which there was much diversity of opinion. The majority were in favour of dividing the cretaceous into three series, and of making the Gault and upper Greensand (Cenomanian) the middle division; but if this were found impracticable in the case of the map of Europe, it was agreed though not without strong opposition to include the Gault in the lower Cretaceous.

The Flysch, it was shown by several geologists, is not a distinct and definite sub-division, but a peculiar petrographical condition of beds that are of various ages, some being cretaceous. It was unanimously agreed to omit the name from the map altogether.

These preliminary questions having been settled, the remaining divisions to be adopted for the map of Europe were discussed, commencing with the lowest, and the following decisions were arrived at.

It was agreed unanimously that the three lowest divisions should be united into a single system, to be termed Archæan.[1] It was urged that some other term than *Phyllites* should be used for unaltered or slightly altered Pre-cambrian beds.

The union of Cambrian and Silurian into a single system with three sub-divisions was supported by 8 votes out of 10 who voted.

The Devonian was recognised as a system divided into three series; it was however pointed out that this system is far inferior in development to the united Cambrian and Silurian.

On the question whether the Permian should remain a distinct system, or be classed as the uppermost series of the Carboniferous, the votes were equally divided. It was however agreed that one sub-division sufficed for the Permian, the Zechstein being represented by a special marking on the Permian colour.

The Trias was not discussed. It should however be mentioned that the old classification under which this system is divided into Bunter, Muschelkalk, and Keuper, is opposed by many geologists, who urge that the alpine sequence, composed entirely of marine beds, is more typical and affords better characters for comparison than that of Central Germany, where two of the sub-divisions, Bunter and Keuper, are nearly or entirely destitute of marine fossils, whilst the fauna of the Muschelkalk is peculiar and local. The alpine beds show that there is no distinction between the faunas of the beds representing Muschelkalk and Bunter respectively comparable with the difference between these two lower marine sub-divisions, and that representing the Keuper, and consequently that a twofold and not a threefold division is indicated.

After considerable discussion the limit between middle and lower Jurassic was drawn below the beds with *Ammonites opalinus* (upper Toarcian) and that between upper and middle Jurassic at the base of the Callovian.

This was practically the close of the session, the cretaceous sub-divisions having been previously discussed. No attempt was made to enter upon the subject of tertiary systems.

[1] At the Berlin congress, as will be seen, the term group was substituted (in this connection) for system.

At a previous sitting, however, the classification to be adopted for igneous rocks had been discussed at some length. The original proposal made at Foix by Professor Beyrich, one of the directors of the map, was to divide igneous rocks into five classes,—granitic, porphyritic, melaphyritic, trachytic, and basaltic.[1] (There was a still earlier proposal by the Hungarian committee in 1881 to adopt five classes, but melaphyre and its allies were omitted and a separate group of modern volcanic rocks added.) At Zürich two proposals were brought forward, one by the Swiss committee of nomenclature, the other by Professor Neumayr, the Austrian member of the International Committee. The former pointed out that, as in Europe, there were very few mesozoic eruptive rocks,[2] it was easy in a map of that continent to divide igneous formations in general into two groups, ancient and modern, and that each of these might be again divided into basic and acid. A fifth sub-division might be made for recent volcanic rocks, but this appeared of more doubtful necessity. Professor Neumayr proposed seven sub-divisions, granites and diorites, porphyries and melaphyrs, trachytes and basalts, and serpentines. The directors of the map accepted the principle of the Swiss Committee's report, but with the addition of a special tint for ancient porphyries (felsite, &c.), in order to distinguish them from granite and its allies, and another as proposed by Professor Neumayr for serpentines.

Another proposition brought forward by Professor Neumayr received general assent. This was a scheme for the preparation and publication, under the guidance of a Committee appointed by the congress, of a *Nomenclator Palæontologicus*, containing the names of all published species of fossil animals and plants with references.

The questions 5, 6, and 7, previously mentioned, were not discussed at the Zürich meeting, nor brought before the congress at Berlin, but replies to some of them were sent in by some of the national committees. A few propositions were made with regard to the colours for palæozoic rocks, but they appear hitherto to have led to no result. The word *phase* was proposed by the Swiss committee and adopted by some others as the equivalent of the term assise.[3] The employment of the word series instead of group for the greater geological divisions (palæozoic, &c.), and of group instead of series for sub-divisions of systems, was considered desirable by several committees (French, Swiss, Spanish, Portuguese). One or two however were opposed to it, and from many no reply was received. It may be remarked here that the council at Berlin decided by a large majority not to reopen any question on which a decision had been taken at Bologna.

Berlin Congress.—After the Zürich meeting of the International Committees very little was done for two years. At the Berlin meeting of the Congress two printed reports were presented, one on the geological map of Europe, the other on nomenclature.

[1] This was virtually founded on the view generally held in Germany that there is a radical petrological distinction between ancient eruptive rocks to which the three first classes belong and later igneous formations.

[2] It need scarcely be remarked that the reverse is the case in India.

[3] No good English equivalent has been suggested for this term. The proposal to use 'beds' in English is not likely to meet with general acceptance.

The report on the geological map of Europe was drawn up by Professor Renevier, Secretary to the Committee, and referred mainly to details of publication, management, &c. The only conclusions of general importance related to colouration and to the classification of rocks. The following is the classification that appears to have been adopted:—

Sedimentary formations.

Quaternary.
{ Pliocene.
Miocene.
Oligocene
Eocene. }
{ Upper Cretaceous
Lower „ (Gault included). }
{ Upper Jurassic.
Middle Jurassic
Lower Jurassic. }
{ Upper Triassic.
Middle Triassic.
Lower Triassic }
Permian
{ Upper Carboniferous.
Lower „ }
{ Upper Devonian.
Middle Devonian.
Lower Devonian. }
{ Upper Silurian.
Lower Silurian.
Cambrian. }
{ Azoic Slates.
Crystalline Schists.
Gneiss. }

Eruptive formations.

Granite, Syenite, &c.
Porphyry
Trachyte, Phonolite, &c.
Melaphyre, &c.
Serpentine
Basalt, Dolerite, &c.
Recent eruptions.

The colours for palæozoic rocks proposed by the Committee, and adopted by the Congress, are *grey* for Carboniferous and *brown* for Devonian. For Silurian a dark green was used in the provisional scale of colours employed in some preliminary trials, but was found to be too nearly similar to the cretaceous colour The question of the colour to be used for Silurian, including Cambrian, was therefore again referred to the map Committee.[1]

[1] It may here be remarked that the adoption of violet for Trias after having been proposed for Silurian by several national committees, and recommended in the printed reports of the International Committee laid before the Bologna Congress, has apparently led to great difficulty in the selection of a suitable colour for Silurian.

For the seven sub-divisions of igneous rocks seven tints of red from bright light-red to deep brownish-red were proposed. The brighter tints were reserved for acid rocks and recent eruptions, browner tints for basic rocks.

Some minor questions of detail were also noticed. Thus it was proposed in cases where the system to which a rock belonged is known, but the sub-division is uncertain, to use the medium tint of the colour with the initial letter of the system by itself. When the sub-divisions are known, but the scale of the map is insufficient to represent them separately, the medium tint of the colour, it was suggested, might also be employed, but to the initial letter should be added the smaller letters or numbers indicating the different divisions.[1] Lastly, in case of beds of which the system itself is doubtful, the colour of the most probable period might be employed, with white spaces, and with the addition of a mark of doubt to the letter representing the system. These points were left to the decision of the map Committee.

It must be remembered that the conclusions accepted by the Congress so far relate solely to the map of Europe. For instance, no opinion whatever has been expressed as to the best classification of igneous rocks. The seven sub-divisions are merely a compromise adopted for the map.[2]

The report of the Committee for establishing uniformity of nomenclature was drawn up by the Secretary, Professor G. Dewalque. It commenced by recapitulating the decisions of the Bologna Congress,[3] then called attention to those paragraphs of the report[4] presented to that Congress on which no vote was taken. The remainder of the report laid before the Berlin Congress was occupied by propositions for the names to be applied to systems and to their principal sub-divisions or series, and for the limits to be drawn in doubtful cases.

The reports of the German, Belgium, Spanish, French, Hungarian, Portuguese, Roumanian, and Swiss committees, were appended. The very full reports of the English committees were printed in English and distributed separately.

So very little of the report was even discussed by the Congress, that it is unnecessary to translate any portion of it. The points on which conclusions were adopted were the following:—

I.—After considerable discussion, it was agreed to class pre-cambrian rocks as a group and not as a system, and to use the term Archæan for this group. A triple division, as already noticed, was adopted for the map, such division to be purely petrological and not to involve the idea of chronological succession.

II.—The term Silurian or Siluric was adopted for the combined Cambrian and Silurian systems. The consideration of the sub-divisions to be introduced in this system was postponed.

[1] For the literal notation, see Rec. G. S. I. xv, p. 74, Rule 7.

[2] It has been repeatedly observed that it is illogical to classify igneous formations by their petrological character, whilst in sedimentary rocks the geological age alone is regarded as a basis for classification and lithological composition ignored. The classification adopted for eruptive rocks is not likely to be generally accepted, and will certainly not be adopted by English geologists.

[3] Rec. G. S. I. xv, pp. 70.-71.

[4] *Ibid*, p. 70.

III.—It was agreed to accept the terms Rhenan, Eifelian, and Taunuenian, for lower, middle, and upper Devonian series, respectively.

IV.—The question whether Permian and Carboniferous should be united into one system, produced by far the best debate in the Congress. The retention of two distinct systems was urged by some German, English, and French geologists, but opposed by others; whilst geologists from other parts of the world almost universally advocated the union of the two. The fact is that in Western Europe the Permian rocks are not only very distinct in lithological character, but they are in many places separated from the Carboniferous by well-marked unconformity Indeed in parts of Western Europe, and especially in England, there appears both lithologically and stratigraphically a closer connexion between Permian and Trias, the two forming together the New Red Sandstone of the earlier geologists, than between Permian and Carboniferous. On the other hand, it was pointed out that the true Permian, the Dyas of some geologists, is peculiar to Europe; that the marine fauna (Zechstein) is closely allied to Carboniferous, and has no claim to separation, some of the species and nearly all the genera being found in true Carboniferous beds; that beds representing the Permian in other countries are merely upper Carboniferous beds,[1] and that distributions founded on lithology and unconformity are only of local value.

The discussion was the more noteworthy because, instead of terminating by a vote, as was done in similar cases in Bologna, where some of the decisions were only carried by very narrow majorities, the meeting accepted the suggestion of Professor Neumayr and abstained from a division.[2] It is however probable that had a vote been taken, a large majority would have been in favour of the union of the Permian with the Carboniferous.

V.—It was agreed to divide the Triassic system into three series, but the limits were not defined.

VI.—The division of the Jurassic system into three series was unanimously adopted. The question as to the limits to be assigned to the different series was postponed, and also the determination as to the affinities of Rhætic beds.

The remaining questions as to the divisions of the cretaceous system, the classification of tertiary systems, and the whole subject of igneous rocks, were practically left almost untouched. No attempt at any decision was made.

[1] I pointed out in reference to this question, the singularly important evidence afforded by the strata of the Salt-range, where, as Dr. Waagen has shown, the upper *Productus*-limestone beds, although they contain far more Triassic genera than the Permian of Europe, and although they yield *Ammonites* and *Ceratites*, are intimately connected by identical species with the middle and lower Carboniferous beds underlying them. Judging by their fauna, these Salt-range upper *Productus*-limestone beds are probably newer than the European Permian (Zechstein), yet there is no reason for classing them in a system distinct from the Carboniferous.

[2] I pointed out, Rec. G. S. I. xv, p. 66, the manifest objection to an attempt in a congress, the majority of members attending which belong to one nation, to settle difficult and disputed questions by a vote.

The committees for the map and for geological nomenclature were re-appointed. a very few personal alterations being made; and it was arranged that meetings should be held in the course of the next two years.

It was determined that the next triennial congress be held in 1888 in London, and, so far as can be determined beforehand, between August 15th and September 15th. A small committee of English members was nominated to carry out the necessary arrangements.

In contrasting the two congresses that I have attended the greatest difference is that, in that of Bologna, there was an endeavour made to settle difficult questions by the vote of a majority, whereas this was no longer attempted at Berlin, t having been recognised by all that a congress is not a body qualified to remove international differences by voting. Irrespective too of the much smaller time given to discussions on such subjects as nomenclature, there was a great falling off in what may fairly be termed geological hobbies, such as the adoption of the solar spectrum as a basis for geological colouration, and a change, for the sake of uniformity, in the terminations of names applied to systems, &c. There was also much less talk, perhaps partly because Germans, though well acquainted with French, are less fluent in speaking it than Italians. On the whole the tendency appears to be to substitute action for discussion, as is seen in committees for the map of Europe and for a *Nomenclator Palæontologicus* having replaced those on map colouration and rules of palæontological nomenclature. The great importance of the congress is clearly due to the opportunity which it affords to the geologists of different countries to meet and become acquainted with each other.

Note on some Palæozoic Fossils *recently collected by* Dr. H. WARTH *in the* Olive group *of the* Salt-range, *by* W. WAAGEN, PH.D., F.G.S. (With a plate.)

This title will appear rather startling to those acquainted with the geology of the Salt-range; but on a closer examination the fact indicated is in reality not so strange as it appears at first sight.

The "Olive group" is more than any other formation of the Salt-range a true Proteus in its composition and general appearance, and, what is even worse, can only with very great difficulty be distinguished from the beds on which it rests, though the junction is always a discordant one. I need only recall the doubt that existed as to the age of the beds in which *Terebr. flemingi*, Dav., was ound. By all previous writers these had been united with the underlying palæozoic beds, whilst in reality they belonged to the "Olive group" and were in time about equivalent to the Deccan traps and the *Cardita beaumonti* beds, as distinguished by W. T. Blanford in Sind.

Just the opposite of what befell Dr. Fleming with regard to the beds containing *Ter. flemingi*, seems to have happened to Mr. Wynne, with certain beds which he united with his "Olive group," whilst in reality they belong to the palæozoic series below. I have myself hitherto accepted this view of Mr. Wynne's, because there were no obvious reasons to doubt it. It must be born in mind that I was sent to the Salt-range, not to control Mr. Wynne's survey, but to study the succession of the different faunas there, and I wisely abstained

from meddling with beds which were then considered to be unfossiliferous. There was indeed no occasion for this control, as Mr. Wynne's survey has proved in all cases perfectly correct. The mistake of having united a single unfossiliferous bed with the overlying series of rocks instead of with the underlying one, only becomes apparent after the age of this bed can be exactly determined.

On page 69 of his Salt-range report[1] Mr. Wynne characterises the group as follows: "Olive, reddish, and white sandstones, calcareous beds, black shales with boulders; *Terebratulæ* and bivalves, 150 to 350 feet." This is, however, only a general characteristic, and chiefly taken from the eastern parts of the Salt-range, as in the western parts neither the Olive sandstones nor the boulder beds have been found within this group. It needs only a look on the sections on pages 190, 194, 206, &c., of Mr. Wynne's report to become convinced of this. In all these western localities the group is composed of variegated sandstones, shales, glauconitic or pisolitic beds and hæmatite, in which fossils are not at all rare. These fossils are very characteristic, and absolutely identical with those found in the *Cardita beaumonti* beds of Sind. The beds with *Terebr. flemingi* belong decidedly to this series. In the eastern parts of the range the section is a quite different one. A few examples taken from Mr. Wynne's report may suffice to illustrate this. On pages 165 and 166 the following section is drawn up from the cliffs below Dandót:—

		Feet.
1.	Nummulitic limestone	200
2.	Coal shales, traces to westward. Talus, room for 150 feet of beds.	
3.	Red shales	56
4.	Light-coloured sandstones	20
5.	Shales	20
6.	Whitish sandstones	14
7.	Red clay or shale	36
8.	Greenish shales	28
9.	Metamorphic pebble conglomerate	12
10.	Red shaly and flaggy zone (salt-pseudomorph band)	120

The beds Nos. 3 to 9 Mr. Wynne considers as representing his Olive group. Here already a 12-feet bed of metamorphic boulders appears at the base of the group. The Olive sandstones, however, are not yet distinctly developed. Further to the east a section has been measured by myself in the vicinity of Sadowal. It is printed on page 154 of Mr. Wynne's report. The section runs as follows, leaving aside the details of the beds above the strata that are here of special interest:—In this section the beds from 13 to 15 must very probably be taken as representative of Wynne's Olive group; it may, indeed, be said that the section is a typical one.

		Feet.
1—12.	Variegated sandstones with coal seams	83
13.	Dark greenish-gray shale and thin-bedded sandstone	30 to 40
14.	Thick grayish-green sandstone with irregular beds of gravelly conglomerate and bivalves	15 to 20
15.	Boulder conglomerate	3 to 30
16.	Dark purple shale with thin bands of greenish sandstone	50
17.	Red thin-bedded sandstones and flags with salt-pseudomorphs	100

[1] Memoirs, Geol. Sur. India, vol. XIV (1878).

The most easterly localities where the group has up to the present been observed are in the country round. Bhaganwala. At page 138 of the report there is a section of the coal locality there, which shows the following subdivisions in these beds:—

	Feet.
1. Yellow fossiliferous nummulitic limestone	11
2. Black shale	8
4. Coal shale, including 3 feet 6 inches coal	14
5. Gray lumpy sandstone	2
6. White ferruginous sandstone, coarse quartz grains and unctnous white clay matrix, with black shaly and carbonaceous veins and strings, and delicate purple and green earthy layers above, conglomeratic at base	21

All these beds are headed "Nummulitic" by Wynne, but the conglomerates at east may represent the Olive series, as it is stated on the same page of the report that large erratic blocks indicate the presence of the group in this neighbourhood.

In these eastern sections the *Cardita beaumonti* beds are nowhere conspicuous, and they have not been known to exist until recently detected at several places of the eastern Salt-range by Dr. Warth, who sent me very numerous fossils, including *Cardita beaumonti* and *Corbula harpa,* from the country round Choya-Saidan-Shah, &c.

These *Cardita beaumonti* beds are situated here between the coal and the Olive sandstones of the Olive group, but are so intimately connected with the coal that these latter very probably will also have to be considered as belonging to the same group.

From these deductions it appears that whilst in the western parts of the Salt-range the Olive group includes nothing but the *Cardita beaumonti* beds, in the eastern parts of the range yet another group of beds is contained in it, of which the boulder bed is the most conspicuous member; and it is to this boulder bed that I wish to draw the particular attention of the reader, as just at the upper limit of it have been found the fossils which are referred to at the beginning of this paper.

The section at a place near Dillour, where most of the fossils have been found, is, according to a communication I have received from Dr. Warth, as follows:—

		Feet.
	Nummulitic limestone.	
	Space concealed; at other places here come the coal-seams and the beds with *Cardita beaumonti.*	
Olive Group .	Olive soft sandstone	150
	Concretions with fossils.	50
	Boulder bed	
	Pseudomorph salt-crystal zone.	

The fossils occur in a very thin bed, just at the top of the boulder bed. They are contained in brownish sandy concretions, which are generally crowded with individuals, in which, however, not very numerous species are to be found. Though the bed has been searched very diligently by Dr. Warth, and a native was occupied for weeks to collect fossils in it, yet the number of species is not greater than ten, some of which have however been found in many hundreds of specimens. The concretions are all of about the same size and mostly of an oval shape. All of them are not fossiliferous: Dr. Warth found only one containing fossils among every twenty of them. But when fossils are present they are often in great numbers.

The most common forms are *Conulariæ*, of which hundreds of specimens have been found. Next come specimens of *Serpulites*, which are however very much rarer: all the other fossils have been found only in sporadic specimens. The most abundant of all is a *Conularia*, which can be identified with all possible certainty with *Conularia lævigata*, Morr., from carboniferous beds of Australia.

1. CONULARIA LÆVIGATA, Morris, Pl. I, fig. 1.

1845. *Conularia lævigata*, Morris: in Strzelecki, Phys. descr. of New South Wales' p. 290, pl. XVIII, fig. 9.

1877. *Conularia lævigata*, (Morr.) Koninck: Foss. Paléoz. de la Nouvelle Galles du Sud, p. 313, pl. XXIII, fig. 1.

This species attains rather considerable dimensions, but by far the greater number of specimens found in the concretions are small young specimens; only exceptionally are individuals met with so large as the one figured by me, or even larger. The species is somewhat variable, as I have tried to illustrate by different figures.

The most striking characters, which always hold good, are—first, the rectangular, not quadratic, section of the cone, the always smooth condition of the ribs, and the very regular distribution of these, so that always ten to twelve can be counted within the distance of 10 mm.

The variability of the shell chiefly consists in the arrangement of the ribs, which are generally arranged in such a manner that in the middle of the faces of the pyramid, where the ribs meet under an obtuse angle, they alternate with each other; sometimes however in one and the same specimen they do not alternate but unite directly with each other, and then form simply bent lines.

The species seems to be most nearly related to *Conularia ornata*, d'Arch. and Vern., from the devonian, and to *Conularia quadrisulcata*, Sow., from the carboniferous period. From both it is different by its rectangular section; from the former also by its smaller apical angle, which is only 15°, whilst it is 20° in *Conularia ornata*, and from the latter by its coarser transverse striation.

There cannot, I think, be much doubt about the determination of this form. The transverse section, the number of ribs, the apical angle, all are identical with *Conularia lævigata*, and thus we can safely unite the Salt-range form with the Australian species.

2. Conularia tenuistriata, M'Coy, Pl. I, fig. 3.

1847. *Conularia tenuistriata*, M'Coy: Ann. and Mag. Nat. Hist., Vol. XX, p. 307, pl. 17, fig. 78.
1877. *Conularia tenuistriata*, (M'Coy) Koninck: Foss. Paléoz. de la Nouv. Gallès du Sud; p. 310, pl. XXIII, fig. 2.

This species is much rarer than the preceding; there is only a single well-preserved specimen of it among the materials at hand. The characters of the species are however very easily traceable, and thus the specimen can be determined with perfect certainty.

The shell must have been extremely long, as the apical angle is not more than 10°. The transverse section of the pyramid is somewhat lozenge-shaped, possessing, however, two broader and two considerably narrower faces. The latter are rather deeply impressed in the middle. The four faces are covered with a rather fine transverse plication. The single folds are broken in the middle of each face and there mostly alternate. The folds are smooth on the top and very fine. There are nineteen to twenty within the space of 10 mm. In the grooves between the folds a very fine oblique striation is observable. These characters will suffice to recognise the species.

As has been rightly remarked by Mons. de Koninck, the species is most nearly related to *Conularia gerolsteinensis*, d'Arch. & Vern., from Rhenish devonian beds, but can be distinguished from that species by the more acute apical angle and the smooth, not granulated, ribs that cover the faces of the pyramid. *Conularia tenuistriata* was originally described, like *Conularia lævigata*, from carboniferous beds of Australia.

3. Conularia cf. irregularis, Kon., Pl. I, fig. 2.

1843. *Conularia irregularis* Koninck: Descr. des anim. foss., p. 496, pl. XLV, fig. 2.
1883. *Conularia irregularis*, Koninck: Faune du Calc. Carb. de la Belgique, Ann. du Mus. Roy., Vol. VIII, p. 222, pl. LIV, fig. 1—8.

There is only a single fragmentary specimen which might perhaps be assigned to the above species: a quite safe determination of the species is however impossible, on account of the very fragmentary state of the single specimen.

Though on a first glance the specimen seems to bear a rather great resemblance to *Conularia lævigata*, Morr., one soon finds on a closer inspection that it is different from all the other *Conulariæ* occurring in the concretions by granulated ribs; also the apical angle is quite different, being about 25° between two opposite angles of the cone. By these characters it approaches *Conularia irregularis* nearer than any other species; moreover as the transverse section of the cone is an elongated rhombus, very much resembling fig. 4 of the drawings in the Annales du Musée Royal.

The specimen is, however, rather small, and the ribs somewhat coarser than as represented by Mons. de Koninck, though they are not dissimilar to the drawings. These discrepancies, however, prevent me from directly uniting the Indian specimen with *Conularia irregularis*.

The species was originally described from the mountain-limestone of Visé.

4. BUCANIA cf. KATTAENSIS W.

1880. *Bucania kattaensis*, Waagen: Salt-range Fossils, I, p. 151, pl. XIV, fig. 6.

Again a specimen which cannot be determined with safety. The specimen consists of an internal cast only, but the enormously broad slitband, the impression of which can be made out, recalls strongly the same feature in *Bucania kattaensis*, wherefore I have united this cast with it.

It would not be at all astonishing that a species of the lower Productus-limestone should occur in the concretions.

5. NUCULA, *sp. indet.*, Pl. I, fig. 6.

It is in general of an oval shape with rather inflated valves. The figured specimen is an exceptionally small one.

It might be compared to quite a number of species, but as the determination of this form is of no value whatever, I shall abstain from such a comparison.

There have altogether been found three specimens of this form.

6. ATOMODESMA (?) WARTHI, Waagen, n. sp., Pl. I, fig. 7.

This species is represented by some not very well preserved specimens, and it is rather doubtful to what genus it should be assigned.

There is no specimen in which the hinge could be seen, but the general form is not dissimilar to *Atomodesma*; I may therefore assign the species to that genus.

It is chiefly characterised by a strongly inflated apical region. The substance of the shell is rather thin, and therefore mostly not well preserved. It shows very fine concentric striation on its outer surface. On the internal casts a more coarse concentric plication appears, which is crossed by a very fine and rather indistinct radial striation.

7. AVICULOPECTEN cf. LIMÆFORMIS, Morris, Pl. I, fig. 8.

1845. *Pecten limœformis*, Morris, in Strzelecki: Physical descr. of New South Wales, p. 277, Pl. XIII, fig. 1.

1877. *Aviculopecten limœformis*, (Morris) Koninck: Foss. Paleoz. de la Nouvelle Galles du Sud, p. 291, Pl. XXII, fig. 4.

The only specimen that has been found up to the present is fragmentary, and very considerably smaller than the one figured by Morris; it can nevertheless be compared in general appearance to that species, as the character of the not-divided ribs is very similar.

Av. limœformis is again an Australian carboniferous species.

8. DISCINA, *sp. indet.*, Pl. I, fig. 9.

A very large *Discina*, of which, however, there is but one imperfect specimen.

Fragments of both valves are preserved, and the slit-like aperture of the lower valve can be well distinguished. Both valves are rather flat. The upper valve seems to be granulated on its outer surface. Otherwise both valves are ornamented only with a fine concentric striation.

As no other characters can be made out, it seems not advisable to express any opinion as to the specific affinity of this shell; nevertheless it must be remarked that we have to deal here with a true *Discina* and not with one of the genera that occur in the *Neobolus* bed of the Salt-range.

9. SERPULITES WARTHI, Waagen, n. sp., Pl. I, figs. 4, 5.

Next to *Conularia lævigata* this is the most common species in the concretions. It belongs to that group of forms which bear no marginal thickenings, and is very nearly related to a species from the lower Productus-limestone to which I have given the name of *Serpulites indicus* W.

From this latter species the present one is distinct by its much smaller size.

This group of forms, without marginal thickenings, has till very recently not been known to occur above the silurian period, but the species from the Productus-limestone demonstrates that such species can occur also in much more recent strata.

10. SERPULITES TUBA, Waagen, n. sp.

Together with the preceding species occurs a much smaller one, with an enlarged trumpet-shaped mouth; I introduce for it the above name. It is much more rare than *Serpulites warthi*.

To sum up, after the description of the several forms we find the fauna contained in the concretions to be composed of the following species:—

Bucania cf. kattaensis W.
Conularia lævigata Morris.
,, *tenuistriata* M'Coy.
,, *cf. irregularis* Kon.
Nucula sp. indet.
Atomodesma (?) *warthi* W.
Aviculopecten cf. limæformis Morris.
Discina sp. indet.
Serpulites warthi W.
,, *tuba* W.

It must be confessed that this fauna is not very large; nevertheless it can positively be affirmed that it cannot possibly be a mesozoic fauna, but that it must be considered as belonging to the palæozoic series. The occurrence of hundreds of specimens of *Conularia* give it an entirely palæozoic character.

The whole fauna is however almost entirely new to the Salt-range; only the *Bucania cf. kattaensis* W. has been formerly described by me from the lower Productus-limestone of Katta. The determination of this species cannot however be made with sufficient certainty, as only a single internal cast is available. Quite different is the case with the *Conulariæ*. One of them (*Con. lævigata*) at least has been found in hundreds of specimens, and its determination is above any doubt; the determination of the other (*Con. tenuistriata*) is also quite safe. Now these two forms are identical with species that were originally described from Australia, from beds there intercalated with coal-seams, and in which at the same time numbers of *Producti*, *Spirifera* and other similar fossils occur, indicating a carboniferous age for those beds. To the same horizon point the

Aviculopecten cf. limæformis Morr. and the *Con. cf. irregularis* K. though they cannot be identified with certainty. The other species (*Nucula sp. ind.* and *Discina sp. ind.*) are new; but they exhibit quite a palæozoic character, as also do the *Serpulites*, or at least they do not contradict the palæozoic age of the whole fauna.

On the whole if we consider th safely or approximately determinable species, which are—

Bucania f. Kattaensis W.
Conularia lævigata Morr.
" *tenuistriata* M'Coy,
" *cf. irregularis* Kon.
Aviculopecten cf. limæformis Morr.

we see that all of them point towards a carboniferous age of the beds in which they have been found.

There is however a circumstance which imposes some caution in this respect; this is the occurrence of the concretions on the top of coarse boulder-conglomerates, into which they may have been transported from afar, having previously been washed out from some other older formation.

When the first concretion containing *Conulariæ* reached me from India, I was convinced that it was a transported pebble and not *in situ* in the bed in which it had been found. But after a time Dr. Warth sent me so many proofs in favour of an opposite opinion, that at last I came to belive that these concretions were *in situ*, and the age of the bed in which they occurred could be judged from them. These proofs were the following:—

1. The concretions occur not irregularly throughout the whole boulder-bed, but are most distinctly restricted to a very thin layer just at the top of the bed, where they occur rather plentifully.

2. This thin horizon has a very regular and constant horizontal distribution, and Dr Warth was able to state its existence over more than ten square miles, everywhere exhibiting absolutely the same characters.

3. The fauna contained in the concretions is a very uniform one, and points distinctly to a single geological horizon. If the bed in which these concretions are contained were of cretaceous age, and the concretions transported, a mixture of the fauna with different foreign forms would be the necessary result, and it is impossible that among the hundreds of fossils that have been collected not a single triassic or jurassic species should occur or even any silicified specimen from the Productus-limestone.

From all these reasons it results with absolute certainty, that the concretions containing the above fossil are *in situ*, and that the bed in which they occur is of carboniferous age.

Thus we have in the eastern parts of the Salt-range two constituents within the Olive group of Wynne, one equivalent in age to the *Cardita beaumonti* beds, of which the Olive group is solely composed in the western parts of the range, and another below it containing a boulder-conglomerate which is of carboniferous age, and restricted entirely to the eastern part of the Salt-range.

There remains some difficulty in deciding what beds should be placed in the upper part and what in the lower part of the divided group. The chief doubt is with regard to the soft olive-coloured sandstones which overlie the bed with *Conulariæ* and contain sometimes bivalves of a *Unio*-like appearance. I should be rather inclined to count these with the upper part, and to restrict the lower part to the boulder-bed; but I cannot give positive data in this respect, and just the contrary may be correct. All depends on future finds of fossils.

This is a matter of no great importance. Of the greatest importance, however, is that we have recognised the "Olive group" to be composed of two members, one of approximately upper cretaceous, and another of carboniferous age.

Some words have yet to be said upon the petrological character of the latter. I have spoken of it as a boulder-conglomerate, and in fact the greater part of this deposit is made up of boulders, often of quite enormous size, true erratic blocks, which are imbedded in a dark-coloured shale, intermixed often with gravel or coarse sand. The rocks of which the boulders consist are all of a very hard nature, beautiful granites of different colours, syenites, different porphyries, greenstones, quartz-rock, &c., but no rocks of a softer nature, like sandstone, &c. They are mixed together in the most irregular manner, and have been taken by Mr. Wynne as indications of the vicinity of a sea-shore. When I visited the Salt-range I observed, however, in these boulder-conglomerates a great number of striated pebbles, and recently Dr. Warth has also sent a number of them to Europe. He writes at the same time that they are so common that he might get any number of them if required. Such scratched pebbles and boulders imbedded in a soft shale are always indications of the influence of ice action, and thus we must admit for the formation of these boulder-conglomerates the collaboration of ice on a grand scale.

We have thus now fixed two characters for the beds in which the *Conulariæ* occur, first that they are of carboniferous age, and second that they have been formed under the influence of ice action.

There remains yet to look out for the equivalents of this boulder-conglomerate in the western parts of the Salt-range, as carboniferous beds are well known to exist there, and they must be in some relation to the carboniferous boulder-bed of the eastern range.

It is a well known fact, that on the whole the Olive group, or perhaps more properly speaking, the *Cardita beaumonti* beds, rest unconformably on the entire palæozoic and mesozoic series of the Salt-range, but the unconformity is such a slight one that in the single sections it cannot be observed at all, and can only be made out by observing that in nearly every section this *Cardita beaumonti* group rests on different beds.

If we start from the west we find at first the *Cardita beaumonti* group but very little developed, a few beds of sandstone and hæmatite is all that can be assigned to it. These rest on jurassic beds. Further east, for instance in the country round Katwáhi, the group is well developed, full of fossils, but rests on the *Ceratite* beds. At Nursingpohár it rests already directly on the compact Productus-limestone, the *Ceratite* beds having disappeared. In the Nilawán the compact limestones have also disappeared, and the *Cardita beaumonti* group rests now

directly on the *Fusulina* beds of the lower productus-limestone. We see that thus the group comes into contact with beds which are more and more low in the series as we proceed further towards the east, and going yet further eastward, we suddenly find the carboniferous boulder-beds with *Conulariæ* appearing below the *Cardita beaumonti* group. These boulder-beds were entirely absent up to this point in Wynne's Olive group, but boulder-beds were not rare to the west at a lower horizon, in, or at the base of, the speckled-sandstone group. Now just where the boulder-beds with *Conulariæ* appear below the *Cardita beaumonti* beds at the base of Wynne's Olive group, the lower part of the speckled-sandstone ought to crop out from below the Olive group, according to the arrangement very regularly observed from the western termination of the Salt-range up to the Nilawán.

We thus have in the first place to look to the speckled-sandstone for an equivalent of the *Conularia* beds in the western Salt-range.

Mr. Wynne says of the speckled-sandstone at page 93 of his report: "This group (No. 5) is even at its commencement conglomeratic in places. It is occasionally so throughout its extension, and far to the west where the groups 2 and 5 lose in thickness greatly, the conglomeratic character increases, the paste being often earthy and the enclosed fragments large boulders of crystalline rock; but it is rather uncertain whether these beds may not belong to the purple-sandstone." This finally expressed doubt has been solved by the Trans-Indus sections which have since been examined by Mr. Wynne and in which the purple-sandstone is exposed below the boulder-bed.

It had for long been a puzzle to me, when I was in the Salt-range, that there should occur there boulder-beds, which evidently were formed under the influence of ice-action, at so different levels, as in the speckled-sandstone and in the Olive group, then supposed to be entirely of cretaceous age; and I could not realise the idea that in a country so near the tropics, at different and recurring periods such a low temperature should have been prevalent as to cause the formation of large ice-masses.

That boulder-beds formed under the influence of ice-action are not rare in the western Salt-range is a well-known fact, and chiefly in the most western parts as well as in the Trans-Indus continuation of the range these beds are of a remarkable development. That ice was really greatly concerned in the formation of these beds appears beyond doubt, partly from the numerous striated and scratched stones that are found in them, partly from the huge erratic blocks which are off and on to be met with. We find these boulder-beds mentioned at different places of Mr. Wynne's report. They are assigned there partly to the magnesian-, partly to the speckled-sandstone, but as the former is barely at all distinguishable in the western sections a mistake is very easy, and it is certainly not a great mistake to assign all these boulder-beds to one and the same large group of rocks. Such boulder-beds are for instance mentioned at pages 214 and 237 of the report. As has been mentioned above they become more constant and less often replaced by sandstones further to the west, and as we approach the Indus the boulder-beds are the only rock that intervenes between the Productus-limestone and the purple-sandstone or the salt-marl. A still more conspicuous development of these boulder-beds is presented in the Trans-Indus

continuation of the Salt-range, and a look into pages 64 and 71 of Mr. Wynne's Trans-Indus report[1] will give a very fair idea of them. Mr. Wynne does not however exactly place these boulder-beds on a level with any bed developed in the Salt-range proper, but on page 26 of the report he considers the speckled-sandstone to be absent, and with regard to the boulder-beds he says: "Similar beds on this horizon" (in the Salt-range proper). On the whole Mr. Wynne seems not quite averse to the idea that all the boulder-beds of these mountain chains should at least be compared to each other if they could not be reduced to one and the same group of beds. He writes on page 68 of his report: "In the neighbourhood of Kafirkot-south the red boulder group, with a thickness of 100 to 150 feet, is occasionally exposed close on the bank of the Indus, appearing from beneath shattered and disturbed carboniferous limestone layers. Here the beds with boulders are somewhat below the top of the group; they contain blocks up to one and a half feet across of red granite, dark basalt, limestone, white metamorphic limstone, quartzose and other indurated rocks, embedded in a dark gray clay: the assemblage strongly recalling both the western Salt-range infra-carboniferous beds and also the much newer conglomeratic clays of Chel-hill in the eastern part of that range, supposed to occupy a cretaceous horizon."

From all that has been said in the foregoing pages it appears that there exists a group of beds in the Salt-range, which is in the eastern parts of the range mostly composed of sandstones, which off and on enclose a boulder-conglomerate, while in the western parts the boulder-conglomerates predominate. This group follows always below the Productus-limestone group and rests either on the magnesian-sandstone, or on the *Neobolus*-beds, or on the purple-sandstone, or at last on the salt-marl. From this it appears that it is in a more close connection with the overlying than with the underlying beds.

As regards the age of this group containing boulder-beds, it is not difficult of determination. The Productus-limestone has been described in detail in my large work on the fossils it contains, and it has been shown there that three divisions can be distinguished, of which the upper two have to be placed on a level with the permian beds of Europe, whilst the lower one, containing *Fusulinæ*, with very great probability must be considered as representing the uppermost horizon of the coal measures. Now the speckled-sandstone which follows below, and which contains the boulder-beds, is most intimately connected with the lower division of the Productus-limestone, and must be placed with it in one and the same group. It thus cannot be lower in the series than the coal-measures of Europe and elsewhere, whilst the magnesian-sandstone and the *Neobolus*-beds, which follow next below, and form together another group of beds probably must be considered as the equivalents of the lower-carboniferous.

After this excursion on the boulder-beds of the Salt-range, we have now to return to our Olive group, and the boulder-bed it contains. There follow three things from the preceding considerations: 1, the boulder-beds of the Olive group appear, geographically, just where the last remnants of the lower part of the speckled-sandstone ought to crop out from below the *Cardita beaumonti* beds;

[1] Memoirs, Geol. Sur. India, vol. XVII, pt. 2 (1880).

2, the boulder-beds in the speckled-sandstone, or which occupy elsewhere its bathrological position, are in appearance extremely similar to the boulder-bed of the Olive series; 3, the boulder-beds of the western Salt-range are probably of the age of the coal-measures; for the boulder-beds of the Olive series have been proved of carboniferous age by Dr. Warth's discovery of fossils in them.

From these three points it results with nearly absolute certainty, that the boulder-bed of the Olive group is the last eastern remnant of the speckled-sandstone group, and that this boulder-bed also must be considered as equivalent in time to the coal-measures.

If thus all the boulder-beds of the Salt-range belong to one and the same group, we have all at once a large glacial formation stretching through the whole Salt-range during the time of the coal-measures. In speaking of a glacial formation, I do not mean that real glaciers were concerned in the formation of these beds; it was probably floating ice coming out of the mouths of rivers, which brought the boulders with it, and deposited them along the sea-shore.

There have, however, still several difficulties to be overcome, before this grand glacial formation can be considered as fairly established.

The sandy strata contained in the palæozoic series of the Salt-range are most evidently a littoral deposit, formed on a very flat, slowly-descending shore. That all these sandy beds, down to the upper limit of the purple-sandstone, are not much different in age and form more or less one continuous series, has been stated already in the introduction to the Salt-range Fossils, and is again affirmed by the discovery of carboniferous fossils in the boulder-beds.

It seems that along the shores of the ancient sea the sandy accumulations were heaped up in dunes, which dwindled down towards the open sea to comparatively thin layers of sandstone and boulders, the latter, supplied by the materials falling down from floating ice, occurring off and on at different horizons.

This supposition alone can account for the great thickness these beds attain towards the east, and the rapid decrease they are subject to towards the west.

In all the foregiong considerations I have not touched upon the question of the age of the "Pseudomorphic salt-crystal zone," as it has been termed by Mr. Wynne, and which follows below the boulder-bed in which the palæozoic fossils have been found by Dr. Warth. That this salt-crystal zone must be palæozoic, as the beds that overlie it are palæozoic, cannot be questioned, but also in their more special age they will not differ much from the rest.

They are composed of sandstones and blood-red clays of very variable thickness, and from the surface of the sandstone flags numerous pseudomorphs of salt crystals stand out. This shows these rocks to have been formed under very peculiar conditions. During their formation great quantities of salt-water must frequently have dried up, giving rise to the formation of numerous salt crystals, which were afterwards dissolved by the influx of fresh water, whilst the hollows left by the crystals were filled up with sandy matter. Such conditions could only have taken place in an estuary, in a back-water behind the dunes, and these rocks must probably be considered as a lenticular intercalation on a large scale between the masses of sandstone of which the lower half of the palæozoic rocks of the Salt-range is composed.

This "Pseudomorph salt-crystal zone" does not, then, present insurmountable difficulties to a rational interpretation; and by degrees more and more clearly these three facts come to light: 1, that there is a group (and only one group) of beds, which contains boulder-conglomerates throughout the whole Salt-range; 2, that this boulder-group extends below the permian and topmost carboniferous beds and is on a level with the coal-measures; and 3, that this boulder-group has been formed under the influence of ice-action.

These three facts are of the utmost importance, and a number of further conclusions may be drawn from them.

Boulder-beds that were formed under the influence of ice action, have long since been known to exist in India, in the Talchir formation, forming the base of the Gondwana system. The age of this Talchir formation has been much contested; and the subject has been discussed in the most admirable manner in several papers by Mr. W. T. Blanford. The most probable conclusion to which Mr. Blanford at last arrives is to consider these beds as of permian age; while most of the previous writers had taken them to be either of lower triassic, or even of jurassic age. All authors were, however, quite agreed upon one point, that these beds had to be compared with certain beds occurring in Australia, in which a number of species of plants, which had been found in the Talchirs and Damudas of India, also occurred.

It was very unexpected, and so much the more interesting, that among the few fossils collected in the boulder-beds of the Salt-range there should again be species identical with Australian forms though they were not plant-remains: *Conularia lævigata* and *Con. tenuistriata*.

In Australia the plant-remains occur in a series of beds with coal seams, in the lowest division of which they are found, together with the marine species mentioned above as occurring in the boulder-beds of the Salt-range.

Thus we have again arrived at three facts of great importance: The Talchir-Kaharbári beds contain a flora identical with, or very nearly related to, a flora occurring in certain beds of Australia together with marine fossils, and at the same time they contain boulder-beds, formed under the influence of ice action; 2, the boulder-group of the Salt-range contains some remains of marine animals identical with species occurring in Australia, together with the above-mentioned flora; 3, the boulder-group of the Salt-range can be determined as of upper carboniferous age, from its position below the Productus-limestone, and chiefly below the lower division of it containing *Fusulinæ* and *Productus semireticulatus* Mart.

From these facts the conclusion may be drawn that the boulder-beds of the Salt-range, and with them the speckled-sandstone of Wynne, are of the same geological age as the Talchirs of the Indian Peninsula, as both are related to the same beds in Australia, the one by its plants, the other by its marine remains. If this be the case, then also the Australian beds, which contain the same fossils as the Talchirs and the Salt-range boulder-group, cannot be more recent than upper carboniferous, or of the age of the upper coal-measures.

From these two conclusions several others follow.

If we have thus found the Talchir-Kaharbári beds to be of the age of the coal-measures, then the other divisions of the Gondwana system can also approxi-

mately be judged. The Damudas will then probably prove to be homotaxically equivalent to the permian of Europe; the Panchet and Rajmahal to the trias (the Kota-Maleri beds must still remain somewhat doubtful); and the Jabalpur and Cutch beds to the jurassic in general. The mesozoic affinities of the plants contained in the lower groups can no longer be an obstacle to such an interpretation, as the geological position of the equivalent beds in the Salt-range is too clear to allow of any other view to be taken. Thus the opinion, so assiduously entertained and defended by Mr. W. T. Blanford, that the exact age of the beds could not be judged with safety from the plant-remains alone, has been gloriously confirmed by the facts now brought forward from Dr. Warth's most important discovery.

If we turn now to Australia, a number of other facts can be ascertained there which are not of less interest. Of the Australian beds that can be compared to different members of the Gondwana system of India, it is chiefly the "Lower coal-measures with marine layers interstratified" which must be placed homotaxically on the same level as the Talchir-Kaharbari beds of the Indian Peninsula, or the boulder-group of North-Western India. In these beds in Australia traces of ice action have not yet been observed. The Newcastle beds which follow next above can perhaps not be separated from the preceding, but the Hawkesbury beds and Bacchus Marsh sandstones must certainly be placed on a level with the permians of Europe. It is only on this horizon that traces of ice action have been observed in Australia; and from this it appears that the glacial action took place at a later date in Australia than in India. The entire Australian series rests on beds that are decidedly lower carboniferous, and this is one proof more that the beds following above are of the age of the coal-measures.

Another country where equivalents of the Gondwana system seem to be present is South Africa. It is now long since the different divisions of the Karoo formation, as it is called in Africa, were compared to the different divisions of the Gondwana system and of the coal-measures of Australia; and we find again a very clear and impartial exposition of the facts relating to this question in Mr. Blanford's presidential address to the Geological section of the British Association for the Advancement of Science, at Montreal. In South Africa the Karoo formation rests partly on carboniferous, partly on Devonian, and at last also on gneissic rock. The lowest division of the formation is the Ecca group which contains a great boulder conglomerate, that has unmistakably been formed under the influence of ice action. These Ecca beds rest conformably on lower carboniferous beds containing coal-plants. The overlying beds are however said to be unconformable to the Ecca beds. There is then evidently something absent in South Africa, but it is not possible to say what extent the missing strata may have had. Perhaps the permian is absent, and the Beaufort beds triassic, or else only the upper part of the coal-measures may be absent, and then the Beaufort beds may be permian. As our knowledge now stands, it is impossible to say which of the two interpretations may be the right one. For us at present it is quite sufficient to state that, with all possible probability the Ecca conglomerates can be considered as the equivalents of the Talchir boulder-beds and of the Salt-range boulder-groups, and are thus of the age of the coal-measures.

The partial identity of the fossil plants found in Australia, in India, and in South Africa has long since led to the idea that in former geological periods a land connection must have existed between those three countries, and thus a by-gone Austro-Indo-African continent has been constructed, stretching through the greater part of the southern hemisphere and nearly equal in extent to the Asiatic European continent of the present period. But it has up to the present been impossible to indicate the exact time of existence of this continent, as the evidence drawn from the plant-remains, was absolutely in contradiction to the one drawn from the marine animals.

Now after all that has been said in the foregoing pages it cannot be doubted any longer that the time of existence of this large southern continent dates at least as far back as the carboniferous period. The northern shores of this continent stretched through India and have been partly preserved in the Salt-range, as well as in Afghanistan, where the Talchir boulder-beds have been stated to extend over large districts, resting on marine lower carboniferous beds. This continent had evidently a well-developed river system, and at the Salt-range there was probably the mouth of a great river. Down these rivers large masses of ice floated while in other parts of the world the coal-measures were being formed; and these ice masses drifted along the shore and, as they melted away, deposited large boulders, gravel and fine silt at different places.

Under such circumstances, apparently, marine animals could not well live on this shore, and it must be considered as very fortunate that some such have been found by Dr. Warth. In Australia the case was different. No ice was there formed during these times, and thus there lived a rich marine fauna there. As it occurs in strata intercalated between plant-beds, it is probably an estuarine fauna.

Of this whole extensive continent there exist in the present period only small fragments. It has been broken up by degrees during triassic and jurassic times, as has been shown by me already in a former paper (*supra*, Vol. X, p. 98). The rocks of which this continent consisted can however be well studied from the erratic blocks which have been brought by the rivers to the shores, so that a large stretch of former land which is now covered by the depths of the Indian ocean may entirely be reconstructed.

The enormous development of boulder-beds that have been formed under the influence of ice action on this ancient southern continent makes the supposition of very low temperatures during those times on that continent an absolute necessity. These low temperatures were not of a local occurrence only, but spread over the whole continent, thus indicating a true glacial period,—a glacial period, however, that was in the beginning restricted to the Southern Hemisphere and only later on spread also to the Northern one.

In the earlier times of the carboniferous period a rather high mean temperature must have prevailed on the southern continent, as luxuriant forests of carboniferous plants were thriving there, of which the remains have been preserved to us in Australia as well as in South Africa. All of a sudden a considerable lowering of the temperature took place, ice began to be formed in South Africa and in India, and all the carboniferous flora was destroyed in these countries as well as in Australia by this low temperature. In the meantime in Australia a new flora

began to appear,—a flora that was suited to support moderate or low temperatures. Notwithstanding the ice that covered part of the southern continent, the flora spread slowly westward from Australia, during upper carboniferous and permian times, to reach Indian and South African regions. This flora was composed entirely of what we call "mesozoic" types, and therefore the beds in which it occurs were generally considered as mesozoic.

During the time when this went on in the Southern Hemisphere, there were the coal-measures deposited in the Northern one, and forests of the greatest luxuriance, composed of carboniferous plants, were thriving there under the influences of a still warm climate.

This warm climate was also not entirely without effect on the Southern Hemisphere. In the beginning of the coal-measures period the marine life along the shores of the southern continent was very poor, as has been stated above. Later on, however, towards the close of that period, the marine animals were no longer much affected by the cold that prevailed on the continent. There were currents of warm water coming from the east, bringing with them a number of American carboniferous animals, which settled in Chinese and Indian areas. (See Kayser: Fauna von Lo-Ping; and Waagen: Salt-range Fossils.)

This state of things continued for a certain time, until in the permian period again a change took place. Now the cold had spread to the Northern Hemisphere (there are traces of ice action in this period in England), and the result was the extinction of the carboniferous flora also in Europe and elsewhere in the north. Now only was the flora of the moderate climate, which we are wont to cal' a mesozoic flora, in a position to spread also over Europe, &c.; and this flora prevailed during the whole mesozoic era.

In the Northern Hemisphere there were no currents of warm water to come thus from anywhere, as the Southern Hemisphere was no longer so very warm, and the marine animals could not withstand the low temperatures to which they were exposed, and the palæozoic fauna perished almost entirely, only few genera escaping.

But also to the Southern Hemisphere the intense cold returned during permian times and after. In Australia we have seen that in the Hawkesbury beds and Bacchus March sandstone, which are probably of permian age, glacial boulder-beds occur. The flora could well endure these low temperatures and did not materially change again, but the marine animals badly felt the changed conditions. Currents of cold water reached the Salt-range towards the end of the permian period. These came from the north and brought with them types of Siberian Cephalopods, thus giving rise to the formation of the Salt-range Ceratite beds; but at the same time they extinguished the life of the rich permian fauna of the Salt-range, the last remnant of the once so rich and beautiful palæozoic fauna.

In this way we come to ascertain two facts, which were not expressed so clearly up to the present. The palæozoic fauna and flora was that of warm climates. The organisms composing these were not able to endure great changes in temperature. As then, towards the termination of the palæozoic times, first in the Southern and later on in the Northern Hemisphere also the general temperature was considerably lowered,—a circumstance which is proved beyond doubt by the frequent occurrence of ice-formed boulder-beds, the whole fauna and flora

necessarily perished. It was afterwards replaced by a more hardy set of organisms, which however only by degrees occupied the place previously taken up by the palæozoic forms. This is chiefly applicable to the land organisms.

We have seen that the palæozoic flora was in the Southern Hemisphere already destroyed towards the middle of the carboniferous period, and was replaced there by forms, such as *Coniferæ*, *Cycadeæ*, *Ferns*, and *Equisetaceæ*, which have been generally considered as typical of the mesozoic floras. This occurrence of these so-called mesozoic types in such ancient strata shows partly that the plants alone, without stratigraphical evidence and the corroborative evidence of marine animals, are not well adapted for a definite determination of the geological age of the beds in which they occur, and this chiefly for the reason, that the plants are greatly dependent upon the climate, and the climatic conditions of remote periods are not sufficiently known to us. The case may be similar with land animals, but of these we know still far less than of the plants in the more remote periods of the earth's history.

Another point that is demonstrated by the occurrence of mesozoic plant types in the carboniferous beds of Australia is, that by this occurrence it is clearly shown that the whole mesozoic land-flora is of an Australian origin, and spread to Europe only in mesozoic times, after place had been made for it by the destruction of the palæozoic flora during the permian period, and after the climatic character of Europe had become favourable for it.

In concluding these remarks I wish to draw the attention of the reader once more to the one cardinal point, that it is demonstrated beyond doubt that towards the end of the palæozoic times a great glacial period occurred, similar in extent and more grave in its effects than the one that took place at the end of the tertiary era, and that thus the earth has passed already through two severe periods of cold.

It has been made possible to ascertain all this by the assiduous investigations of my old friend Dr. H. Warth, who has thus made one of the most important discoveries that ever could be made in the Salt-range.

EXPLANATION OF THE PLATE.

Fig. 1.—Conularia lævigata, Morris: 1*a*, *b*. views from different sides, natural size; 1*c*, transverse section of the shell; 1*d*, *e*, different parts of the surface, enlarged.

Fig. 2.—Conularia cf. irregularis, Koninck: part of the surface, enlarged.

Fig. 3.—Conularia tenuistriata, M'Coy: 3*a*, lateral view, natural size; 3*b*, part of the surface, enlarged; 3*c*, transverse section of the shell.

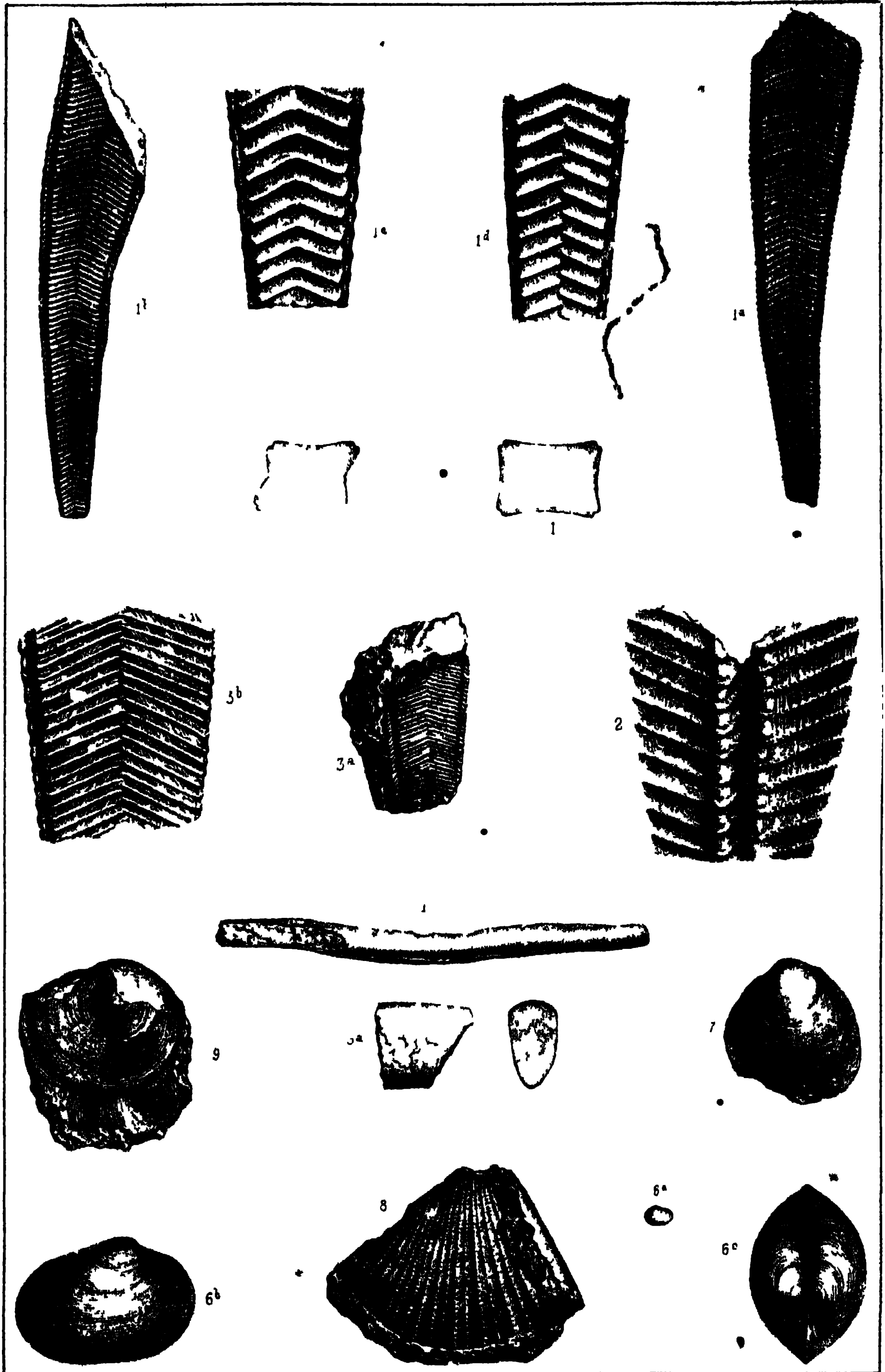
Figs. 4, 5.—Serpulites warthi, Waagen, n. sp.: views from above and from the side, both natural size.

Fig. 6.—Nucula sp. indet.: 6*a*, natural size; 6*b*, *c*, enlarged.

Fig. 7.—Atomodesma (?) warthi, Waagen, n. sp.: partial internal cast, natural size.

Fig. 8.—Aviculopecten cf. limæformis, Morris: fragment of the shell, natural size.

Fig. 9.—Discina sp. indet.: fragments of both valves, natural size.



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Memorandum on the Correlation *of the* Indian *and* Australian coal-bearing beds, *by* R. D. OLDHAM, A.R.S.M., *Deputy Superintendent Geological Survey of India.*

In the spring of 1885 I was deputed, in extension of privilege leave, to visit and examine the coal-measures of New South Wales and Victoria, with a view to elucidating, if possible, the vexed question of their relations to our Indian coal-measures. Accordingly I reached Melbourne on the 11th August and went on to Sydney, whence I proceeded to Newcastle to examine what I may call a classical section in Australian geology.

I had intended, besides, to examine in detail the section in the southern coal-fields and in the Blue Mountains as well as the beds of Bacchus Marsh in Victoria; but a relapse of malarious fever, originally contracted in India, interfered considerably with my movements, and I was compelled to sail from Melbourne on the 2nd September, having only been able to examine the section west of Newcastle and pay a flying visit to the Blue Mountains. With respect to the other localities mentioned above, I had to be content with such information as could be obtained from published reports, and in conversation with those who had examined the ground. I am consequently unable to give the connected account of the Australian coal-bearing series I should have wished to; but as regards the question of the relative age of our Indian coal-measures and those of New South Wales this is of little importance, seeing that the Australian geologists have not yet been able to connect the beds as exposed in the different coal-fields with each other, and with the typical section west of Newcastle to which they must all be ultimately referred. Such observations as I was able to make will be embodied in the following note.

Though it has practically no bearing on the question, it may not be out of place to note the resemblance in lithological characters between certain members of the Australian carbonaceous series and of the Gondwana series in India; thus, at Newcastle may be seen beds of coarse-grained soft whitish sandstone containing a considerable proportion of decomposed felspar and very like some of the Barakar sandstones; again, the boulder beds below the coal-measures are often identical with the similar boulder beds of the Talchirs in everything but the presence of marine fossils; but I attach no value to these lithological resemblances except in the latter case, and then only in so far as they indicate a condition of deposit which, considering the latitudes they are found in and the nature of the beds they are intercalated with, must have been of an exceptional and transient nature.

Introductory.

The relative ages of the Indian and Australian coal-measures have long been a question of great interest to geologists, and in spite of the amount that has been written on the subject and the ability of the writers there is probably no geological question more involved in doubt and difficulty.

The points in dispute are four—1st, the age of the members of the Indian coal-bearing formation, or Gondwana series, as compared with the coal-bearing series in Australia, and more especially of the coal-measures in either country; 2nd, the ages of the members of the Gondwana series as compared with the members of the geological sequence in Europe; 3rd, those of the Australian beds

compared with the same sequence; and 4th, the relative ages of beds exposed in different parts of Australia.[1]

When first the plant fossils of the coal-measures of India (Damudas) and of Australia (Newcastle beds) became at all known, a similarity between the two floras was noticed which naturally led to their being considered as of contemporaneous origin. In both *Glossopteris* was abundant, and the species *G. browniana* (as well as other species then supposed to be identical) was found in both; both contained a species of *Vertebraria*, another of *Phyllotheca*, which were believed to be identical, and are certainly closely allied to each other, while the former genus was till recently unkown from any other formation but the two in question.

Conflict of opinion.

The contemporaneity of the Indian and Australian coal-measures being taken for granted, the second and third of the points in dispute became connected with each other. In Australia two schools arose,—one, headed by the late Rev. W. B. Clarke and those who had examined the beds in the field, reasoning from the close connection of the Newcastle coal-measures with beds containing a marine fauna closely allied to that of the carboniferous beds of Europe, argued that the Newcastle beds were of carboniferous or at any rate late palæozoic age; the other, headed by Professor McCoy and others who had never seen the beds *in situ*, reasoned on what they declared to be the characteristically mesozoic facies of the flora, and on this ground alone, not satisfied with declaring that the beds must be of jurassic age, impugned the accuracy of some of the Rev. W. B. Clarke's statements. In accordance with this divergence of opinion regarding the Australian beds there was a corresponding difference as to the age of our Indian coal-measures; some of the most prominent of the Europe palæophytologists looked upon them as of mesozoic age, while the members of the Indian Geological Survey who had examined the same beds in the field regarded them as of late palæozoic age on the ground of the resemblance of their flora to that of the Australian coal-measures, accepting with regard to these last the opinion of those who had examined them in the field. But as regards the beds above the coal-measures, and so intimately associated with them that they could not be looked upon otherwise than as subordinate members of one great series embracing the coal-measures also, it was acknowledged in both countries and by both parties that they should be regarded as of mesozoic age.

Such was the state of opinion on these questions when Dr. Feistmantel examined the floras of the sub-divisions of the Gondwana series and not only classed them all as of mesozoic age, but even attempted to correlate them to particular horizons of that period; and moreover after a detailed examination of the flora of the Australian coal-measures declared that it was not nearly so closely related to

[1] The Australian series as exposed in the districts between Sydney and Newcastle and the country west of that place is divided by Australian geologists as follows. The nomenclature of the subdivisions, especially in the lower part of the series, is not fixed, but the terms given below will be used in this paper. For the series as a whole I shall use the term Carbonaceous, suggested by Prof. McCoy.

1. Wianamatta shales.
2. Hawkesbury sandstones.
3. Newcastle beds,—or upper coal-measures.
4. Upper marine beds with carboniferous fauna.
5. Stony Creek beds,—or lower coal-measures.
6. Lower marine beds with carboniferous fauna.

that of the Indian beds as had been supposed, and that it could consequently not be appealed to as proving the palæozoic age of the Damudas in India.

Conflict as to facts of superposition in Australia.

But in Australia the dispute was not confined to the conclusion to be drawn from acknowledged facts, but, strange as it may seem, the very fundamental facts of the superposition of the beds was disputed. At the base of the sandstones and shales containing seams of coal and known as the Newcastle beds there is a great thickness of beds from which a marine fauna, closely related to that of the carboniferous period in Europe, has been obtained.[1] These marine beds are divided into an upper and a lower sub-division by a band of sandstones and fine conglomerates containing some seams of coal, and as these beds yielded species of *Glossopteris* and other similar forms which were declared to be characteristically mesozoic, it was assumed that the superposition of these beds by others containing a palæozoic fauna must be only apparent and in reality due to inversion or faulting.

Description of section.

Such a conclusion however could not be allowed by any one who had seen the ground where these beds are exposed. The section is fortunately easily accessible by the Great Northern Railway starting from Newcastle and the beds are well exposed in the frequent cuttings. There are two exposures of these lower coal-measures on opposite sides of an anticlinal, one at Stony Creek, 2 miles west of Branxton, and the other at Greta, 10 miles further west. At both places the dip is moderate and steady, to east-south-east at Stony Creek, to west north-west at Greta; at both places the section is practically continuous, and the marine beds may be traced dipping under the coal seams and a short way above them again reappearing. The re-appearance of the seam on the opposite side of the anticlinal, and the absence of any duplication of the seam are conclusive against any theory that the appearances are due to inversion or strike fualts, while if further proof were necessary it would be found in the fact that both at Stony Creek and Greta shafts have been sunk through the marine beds into the coal, and at the former place through it into more marine beds,[2] thus clearly showing that the coal measures are inter-bedded with the marine beds.

No Gondwana horizon directly referable to the New South Wales section,

but Talchirs represented in Victoria.

It is unfortunate for our present purpose that none of the sub-divisions of the Gondwana series in India can be definitely and directly correlated with any of those of the carbonaceous series as exhibited in the Newcastle section where their relative position is clear and free from doubt. But in Victoria there are some beds containing *Gangamopteris*, known as the Bacchus Marsh beds, which seem to be the equivalents of the Talchirs. The flora of these Bacchus Marsh beds is poor, consisting, so far as is known, of only three species of *Gangamopteris*;

[1] According to De Koninck (quoted in Rev. W. B. Clarke's "Remarks on the sedimentary formations of New South Wales," 4th Edition, Sydney, 1878, Appendix XVI "C," pp. 144-148) out of 249 species known, 81 are found in the carboniferous beds of Europe.

For a fuller account of the stratigraphy of these beds, and the history of this dispute, see Rev. W. B. Clarke's "Remarks on the sedimentary formation of New South Wales," 4th Edition, Sydney, 1878.

[2] I am indebted to Mr. C. S. Wilkinson for this information.

but, as Dr. Feistmantel has shown, of these three species one is identical with, another closely allied to, species found in the Talchir beds of India.

Palæontological

But their palæontology is not the only connection between the two, for, like the Talchirs, the Bacchus Marsh beds contain abundant evidence of the action of floating ice. According to the late Sir R. Daintree, there are "strata, mainly composed of fine mud, dotted throughout with various sized, generally rounded, pebbles, and those pebbles mostly unknown in the vicinity, and some not yet seen in place so far as the Geological Survey has extended a minute examination;" [1] further on he says that "blocks of granite," in some instances over a ton in weight, are found embedded in a matrix of soft mud;" [2] and in the last progress report by the Secretary for Mines in Victoria, Mr. Murray states, on the authority of the late Sir R. Daintree, that some of these granite boulders resemble no granite that occurs as a rock-mass nearer than Queensland.[3]

and physical resemblances.

It is impossible to account for the formation of such beds as these except by the agency of floating ice in large masses, and as both the Talchirs and the Bacchus Marsh beds show that when they were deposited the climate was much more severe than that now prevalent, we may take this as indicating that during their deposition there was a widespread glacial epoch corresponding to that which is known to have occurred in post-tertiary times. This consideration, whatever weight might be attached to it if stood by itself, may certainly be said to corroborate the fossil evidence, and we may consequently take it as certain that the Talchir and Bacchus Marsh beds are the representatives of each other.[4]

Evidence of glacial action.

I am not aware that any attempted correlation of these beds with a definite horizon in New South Wales was published before Dr. Feistmantel in 1880 gave it as his opinion that they were the equivalents of the Hawkesbury sandstones. This opinion, so far as I can glean from his published writings, was based on the so-called lower mesozoic facies of the Bacchus Marsh flora, and was supposed to be confirmed by Mr. C. S. Wilkinson's discovery of what he believed to be evidence of glacial action in the Hawkesbury sandstones. Mr. Wilkinson thus describes this evidence—"In the sections exposed in the quarries at Fort Macquarrie, Woolloomooloo, Flagstaff hill and other places, may be seen angular boulders of shale [5] of all sizes up to 20 feet in diameter, embedded in the sandstone in a most confused manner, some of them standing on end as regards their stratification, and others inclined at all angles. They contain the same fossil plants that are found in the beds of shale from which they have evidently been derived. These angular boulders occur nearly always immediately above the shale-beds,

Correlated with Hawkesbury beds by Dr. Feistmantel.

Glacial action in Hawkesbury sandstones.

[1] Geological Survey. Report on the Geology of the District of Ballan by Richard Daintree. Melbourne, 1866, p. 10.

[2] *Ibid.*, p. 10

[3] Geological Survey. Progress report by the Secretary for Mines, Melbourne, 1881, p. 80.

[4] See *Feistmantel*, Rec. G. S. I. XIII. 257 (1880).

[5] Which is interbedded with the sandstones.

and are mixed with very rounded pebbles of quartz; they are sometimes slightly curved as though they had been bent while in a semiplastic condition, and the shale-beds occasionally terminate abruptly as though broken off." [1]

Not comparable with that of Bacchus Marsh.

Although it is difficult, if not impossible, to account for these appearances, except by the action of ice in some form or other, yet it is evident that they are by no means comparable with the proofs of glacial action exhibited by the Bacchus Marsh beds. The angular form of the fragments of shale shows that in some manner or other they must have been indurated before disturbance, and it is impossible to account for this induration of what must then have been recently deposited mud except by the freezing of the interstitial water. This supposition would accord with the general nature of the evidence, which indicates the action of ground-ice such as is formed during the severe winters of North America rather than the presence of large masses of floating ice; and hence does not necessarily indicate so severe a climate as that afforded by the Bacchus Marsh beds of Victoria.

Glacial action in lower carboniferous marine beds of New South Wales.

But there are in New South Wales conglomeratic beds which are strictly comparable with those of Bacchus Marsh; these are the marine beds with carboniferous fauna, Nos. 4 and 6 of the scheme on page 40 (note). I am not aware of any previous published notice of the evidence of glacial action they afford, but as long ago as 1861, the lithological resemblance between beds of presumably the same age in the Wollongong district and the boulder-beds of the Talchirs was noticed by the late Dr. T. Oldham,[2] and when looking up the

[1] Notes on the occurrence of remarkable boulders in the Hawkesbury rocks by C. S. Wilkinson, F.L.S., G S., Govt. Geologist. Trans. Roy. Soc. N. S. W., Vol. XIII, page 105 (1884).

[2] Mem. G. S. I., III, p. 209 (1863). As the volume is out of print and difficult to procure, I reprint the passage referred to, as it is of interest in the present juncture.

Speaking of a collection of specimens of Australian rocks procured and sent by Sir William Denison, he says,—

"And still further, many of the lower beds of the Australian group, there so abundantly rich in marine fossils, are very similar to many of the beds in the Indian *Talchir* series. There is the same mixture of pebbles, and large rolled masses in a matrix of fine silt; and much of this silt is of exactly the same peculiar bluish-green tint, so characteristic of these beds in this country, and which, once seen, can never be mistaken.

"I would not be misunderstood as desiring to give any great weight to a similarity in mineral texture or lithological aspect, in attempting to ascertain the true position of these rocks. But I am satisfied that this identity has a value, and by no means a light value, when, taken in connexion with every other point of evidence which is available, it is found in all cases tending to turn the balance in the same direction. And, basing my views on these considerations, I ventured to hold out a prospect in anticipation that future researches would enable a more accurate and detailed parallelism to be established between the rocks in both these countries, portions of which were now known to be synchronous, and that, while in all probability it would be found that starting from the common datum line of the coal-bearing rocks in either land, the sequence upwards would be established from Indian researches in this country, apparently supplying links wanting in Australia; on the other hand we should be enabled to supplement the evidences of the succession downwards (which is deficient in India) by a reference to Australian groups. As yet we have not been able to trace the existence of any marine deposits in this country of the same age as the 'Wollongong' sandstones of Australia, but there is nothing whatever in the few plants which occur in our Talchir beds which would militate against their being of the same general age (which I am disposed to think they are)."

literature of this controversy I was much struck by the passage. That any special stress should have been laid on the resemblance was not to be expected, for when the words were written the glacial origin of the Talchir boulder-bed had not been universally acknowledged, the very idea of a glacial epoch was still strange, and no one had yet dreamed of a palæozoic glacial epoch, still less of using such a conception in the correlation of distant deposits. But when I found that in Mr. W. T. Blanford's reply to Dr. Feistmantel[1] no notice was taken of this resemblance, although Mr. H. F. Blanford's suggestion, that the glacial beds of the Permian in England and the Talchirs in India were contemporaneous is quoted, I concluded that private information of later date had led to a modification of the views expressed as to the lithological resemblance of the beds.

Nevertheless I determined to pay special attention to this point, and was not surprised on visiting the section west of Newcastle, to find that the marine beds showed abundant traces of glacial action. Blocks of slate, quartzite and crystalline rocks, for the most part sub-angular, are found scattered through a matrix of fine sand or shale, and these latter beds contain delicate *Fenestellæ* and bivalve shells with the valves still united, showing that they had lived, died and been tranquilly preserved where they are now found, and proving, as conclusively as the matrix in which they are preserved, that they could never have been exposed to any current of sufficient force and rapidity to transport the blocks of stone now found lying side by side with them. These included fragments of rock are of all sizes, from a few inches to several feet in diameter, the largest I saw being about 4 feet across in every direction as exposed in the cutting, and of unknown size in the third dimension; but I was informed by Mr. Wilkinson that in these same beds he has seen boulders of slate, &c., whose dimensions may be measured in yards.

It is impossible to account for these features except by the action of ice floating in large masses,[2] and I had the good fortune to discover, in the Railway cutting near Branxton, a fragment beautifully smoothed and striated in the manner characteristic of glacier action, besides at least two others which showed the same feature, though obscurely. This seems to show that the ice was of the nature of icebergs broken off from a glacier which descended to the sea-level.

Glacial evidence at Wollongong in Blue Mountains;

Beds of similar structure and indicating a similar mode of origin are also found at Wollongong, south of Sydney, and in the Blue Mountains. Though these have not been traced into connection with the marine beds west of Newcastle, the similarity of their position, fauna, and physical aspect, all leave little room for doubt that they are of the same age.

and in Queensland.

In Queensland beds of similar aspect have been described by Mr. R. L. Jack. These beds—also of marine origin, and indicating the presence of ice floating in the sea by which they were

[1] Rec. G. S. I, XI, page 148 (1878).

[2] Roughly speaking, it may be said to take 16 cubic feet of fresh-water ice floating in sea-water to float a cubic foot of granite, or 14 cubic yards to float 1 ton. It must be remembered that many of these fragments probably came from a distance, and that the ice was melting all the while. These figures must be reduced by two fifths if the rock is supposed to be immersed.

deposited[1]—contain 22 species of fossils, so far as the fauna is known, and of these 15 are common to the New South Wales marine carboniferous beds, the other 7 not having as yet been found to the southwards.

A "glacial epoch"

From what has been said it will be seen that over the greater part of Eastern Australia beds are found which, by their included fossils, are shown to be homotaxially equivalent, and which agree in indicating that during their deposition the seas under which they were formed bore on their surface masses of floating ice such as are now only seen in much higher latitudes than are occupied by any part of Australia. It would seem, then, that towards the close of the palæozoic era there was a widespread glacial epoch wh[illegible] effects were felt over the whole of what is now Eastern Australia,

to which the Bacchus Marsh beds should be referred.

and, if we allow this form of argument at all, it is to this period that we must refer the Bacchus Marsh beds rather than to that of the Hawkesbury sandstones which do not indicate so severe a climate.

Palæontological evidence.

The palæontology unfortunately does not help us to a definite conclusion. *Gangamopteris*, the only genus known from the Bacchus Marsh beds, has not so far been found either in the lower coal-measures of New South Wales, or in the Hawkesbury sandstones, but from the Newcastle beds, intermediate between them, two species of *Gangamopteris* have been obtained[2] of which one is identical with, and the other allied to, Bacchus Marsh forms.

The flora of the lower coal-measures comprises 7 species belonging to 4 genera;[3] of these, 4 belong to the genus *Glossopteris*; this latter is therefore, so far as the flora is at present known, the predominant genus, as is also the case in the Newcastle beds; further, one species, *G. browniana*, is also found in the latter; and besides this, the genera *Phyllotheca* and *Noggerathiopsis* are common to the two floras, while *Annularia* is the only genus which has not, so far, been found in the Newcastle beds.

The Hawkesbury beds have only yielded two species of plants; in both cases the genus is represented in the Newcastle flora, and in one case, *Sphenopteris alata* Bgt., the Newcastle form, is only separated as a variety by Dr. Feistmantel. But if we group the Hawkesbury and Wianamatta beds together, as Dr. Feistmantel has done, we have 8 species belonging to 7 genera, of which but 1 species and 3 genera are common to the Newcastle flora.

From the facts just detailed it will be seen that so far as there is any balance

[1] Report on the Bowen River Coalfield, by R. L. Jack, F. G. S., Brisbane, 1879.

[2] *G. angustifolia*, McCoy, and *G. clarkeana*, Fstm., the latter being represented by *G. spathulata*, McCoy, in the Bacchus Marsh beds.

[3] The flora of the lower coal-measures according to Dr. Feistmantel (Tr. Roy. Soc. N. S. W., XIV, 103) 1880, is as follows:—

Phyllotheca australis Bgt.
Annularia australis Fstm.
Glossopteris browniana Bgt.
" " v. *præcursor* Fstm.
G. elegans, Fstm., *G. primæva*, Fstm., *G. clarkei*, Fstm.
Nöggerathiopsis prisca, Fstm.

at all, the Newcastle flora is more closely allied to that of the lower coal-measures than of the Hawkesbury beds.

Stratigraphical evidence.

As regards the stratigraphical relations of the beds, the Newcastle coal-measures are, so far as is known, perfectly conformable to the lower marine beds. On the other hand, though no unconformity has been traced between the Newcastle and Hawkesbury beds, yet if the coal-measures in the Blue Mountains are the representatives of the former,—and the balance of probability is very much in favour of this supposition,—there must be an unconformity and overlap of the Hawkesbury sandstones on the beds below them.

Turning to Victoria, we find that besides the Bacchus Marsh beds the only other rocks which can be referred to any portion of the carbonaceous series in New South Wales, are what are known as the *Tæniopteris* beds which are shown by their included fossils to be homotaxial with the Wianamatta beds or those immediately above them. Owing to the large surface covered by lava flows in Victoria, the exact relation of the *Tæniopteris* and *Gangamopteris* beds is not known, the two not having been found in contact; but there can be no doubt that the latter are completely overlapped by the former, which are frequently found in immediate contact with the silurian slates. I was further informed that the difference in the degree of induration of the two was such as to indicate a considerable difference of age, so that it would be improbable that they could belong to two periods so close to each other as the Hawkesbury and Wianamatta periods.

Contemporaneity of Talchir and carboniferous marine beds.

Seeing, then, that the palæontology and stratigraphy of the beds, so far from contradicting the conclusion derived from the evidence of glacial conditions, are either neutral or support it, we may conclude that the carboniferous marine beds of New South Wales are the most probable equivalents of the Bacchus Marsh beds of Victoria and hence of the Talchir beds of India.

Homotaxy of Damudas and Newcastle beds.

As a corrollary from the above conclusion, it would follow that the Damudas and Newcastle beds are far more nearly contemporaneous than Dr. Feistmantel will allow, and that the Gondwana series as a whole ranges from towards the latter end of the palæozoic into the secondary era, representing in part the interval between those two eras of European geology.

This was the opinion long held by the members of the Geological Survey of India, and was first seriously questioned by Dr. Feistmantel, who ascribed all the sub-divisions of the series to horizons in the mesozoic rocks of Europe, and also declared that the affinities between the Damuda and Newcastle floras were not such as to justify their being regarded as homotaxial.

It will be necessary therefore to see what these affinities are, and whether the difference between the two floras is such as to invalidate the conclusion I have formulated above.

Palæontological relations of Damuda and Newcastle beds.

To begin with, both floras are marked by the predominance of the genus *Glossopteris*, which, in the Newcastle flora, comprises 9 out of 26 species, or 35 per cent. of the total number of species, and 19 species out of 63, or 30 per cent. of the total number

of species in the Damuda flora; of these, one species, *G. browniana*, is identical in both cases, and 3 Newcastle species, *G. linearis*, *G. ampla* and *G. parallela*, are represented by the allied Damuda species, *G. angustifolia*, *G. communis* and *G. damudica*. The genus *Phyllotheca* is represented in both floras, and the Australian form is allied to, and was long considered identical with, the *P. indica* of the Damudas. *Vertebraria* is found in both series, and is only known elsewhere from the "jurassic" beds of Siberia. *Sphenopteris alata* Bgt. is another species represented in allied forms in the Damuda flora, and the species *Gangamopteris angustifolia*, McCoy, is common to the two floras. Besides these the genus *Nöggerathiopsis* is represented in both floras, so that we have in all 6 genera and 2 species common to the two floras, besides 5 species represented by allied forms. On the other hand there are 3 genera out of a total of 9 not represented in the Damuda flora.

It may be that the resemblances between the two floras are not sufficient to justify our placing them, even approximately, on the same horizon; yet it cannot be said that the differences are such as to preclude the beds from which they were obtained from being regarded as, at any rate, approximately homotaxial with each other. I avoid the word contemporaneous for, though I think that probably it might be used in connection with the Talchirs and Bacchus Marsh beds, I see no possibility of arriving at any conclusion as to whether the Damudas and Newcastle beds were or were not contemporaneous; in all probability the two periods overlapped somewhat, and the affinities between the Hawkesbury and Wianamatta floras and that of the Damudas, as well as the internal evidence of that flora itself, would indicate that the latter was probably of somewhat later date than the Newcastle period.

In the foregoing pages I have not alluded, except incidentally, to the position of either the Australian or the Indian coal-measures in the European sequence. This question is altogether too large and complicated for me to take up at present when debarred from access to any scientific library, and has besides been already so well threshed out that I could hardly gather any grain by going over the straw again. This same cause—want of access to books—has prevented me from giving as full references to previous literature as I should have wished to do; but I have endeavored as far as possible to acknowledge my indebtedness to previous writers, and in conclusion I can but express my obligations to all those who assisted me in my enquiries during my visit to Australia, and in particular to Mr. C. S. Wilkinson, Government Geologist of New South Wales, and Mr. R. F. Murray, Government Geologist for Victoria, for the unreserved manner in which they placed all their information and experience at my disposal.

CAMP, AJMERE,
2nd November 1885.

Afghan *and* Persian Field notes, *by* C. L. GRIESBACH, F.G.S., *Deputy Superintendent, Geological Survey of India, on duty with the Afghan Boundary Commission.*

Introduction.—Since writing my last short report on the geology of the Herat province,[1] I have been moving about the Herat valley and Eastern Khorassan, whenever I could obtain permission to do so from Her Majesty's Commissioner.

From Bala Murghab, where our Commission remained during the extreme cold weather of last winter, we moved about the middle of February last, marching *viâ* Kila Maúr and Chaman-i-Béd to Gulrán. There General Sir Peter Lumsden, G.C B., gave me permission to examine some of the ranges in Eastern Khorassan, and accordingly I spent some time in studying the rocks of the Bezd and the Estoi ranges, rejoining the Commission at Tirpúl. From there, I made a short trip to the Doshakh range, and afterwards went for some time to the hills north of Herat. Later on an opportunity occurred to visit the Davéndar range east of Herat, and the march of the Commission to Thagan Robat gave me an opportunity of revisiting the Turmust range. In August last Colonel Sir West Ridgeway, K.C.S I., gave me permission to go again to Eastern Khorassan, where I remained over two months, extending my excursions as far west as the turquoise mines of the Nishapur district.

I have already given a short sketch of the geological structure of the Herat province as far as it has come under my own observation. I have little to add to this and some to modify. In publishing these notes now, it must be clearly understood that many of the observations contained in them may hereafter have to be modified when the material brought together will have been worked out and compared with collections from other parts of the world.

The following formations are represented in the Herat valley and Khorassan:—

Recent and aerial.	Alluvial deposits, fans, blown sand.	Igneous rocks.
POST-TERTIARY	"Loess" beds, with mammalian bones, of Badghis. Red and white clays with sandstone and gypsum deposits. Conglomerate and sandstone } Tirpul beds. Plant shales }	
MIOCENE . . .	Calcareous sandstone and clays, with *Ostrea multicostata* Desh. in Badghis and Khaf. Conglomerate and sandstone of Firaiman near Mashhad.	
EOCENE . . .	Grey shaly limestone with Brachiopods. Coral limestone with nummulites. Grey shales and limestone with nummulites.	Rhyolites and trachytes.

[1] Rec. Geol. Surv. of India, Vol. XVIII, Part I, page 57.

Recent and aerial.	Alluvial deposits, fans, blown sand.	Igneous rocks.
CRETACEOUS . .	Upper { Coral limestone with Hippurites. *Inoceramus cripsi*, Mant., zone. Light-coloured marls. Lower { Dark shales. Trigonia limestone.	Basaltic rocks. Syenitic granite.
PLANT-BEARING SYSTEM. Jurassic and rhætic .	Red grit group; marine limestone with Brachiopods; Paropamisus, Estoi range, &c. Sandstone with marine fossils and Gondwana plants, Gaukharchang pass, &c., &c. Marine limestone,—Kelat-i-Nadri section.	Melaphyre and great masses of felsite porphyry.
PLANT-BEARING SYSTEM. Talchirs? Trias and permian.	Conglomerates, Brachiopod limestone, sandstone, green shales, thin leafy coal and plant-remains. Kholi Biaz section, &c. Palezkar beds.	Melaphyre.
CARBONIFEROUS .	Massive dark limestone and sandstone with many fossils; Davéndar range, &c., &c.	
OLDER PALÆOZOIC .	Limestone and calcareous sandstone; fossils; Dehrud pass.	Trap.

The hill ranges of the Herat province and Eastern Khorassan are all structurally connected, and form long and generally parallel lines of anticlinal folds, which nearly all show much the same succession of beds. The intervening wide troughs of the valleys are filled by tertiary and later deposits. By far the largest share in the structure of these ranges belongs to the beds of the plant-bearing (permotrias and jurassic formations) and to the cretaceous systems. The carboniferous and older palæozoic rocks I only met in a few sections.

Palæozoic rocks, carboniferous and older palæozoic formations.—I found rocks belonging to these systems in the Davéndar and the Doshakh ranges in the Herat province, and in the Bizd and Binalut ranges of Khorassan.

The most complete section of palæozoic rocks I have yet met with in Khorassan, is the one between the villages of Dehrúd and Gulistán on each side of the Dehrúd pass, which crosses the Binalut range south-west of Mashhad. The structure of the range is that of an anticlinal fold, in some places showing inversion and much disturbance of the strata by crushing. Igneous rocks, too, obscure a great deal the actual succession. The carboniferous and older rocks are seen between the village of Dehrúd (4,800′) and the top of the pass (8,750′).

Lower carboniferous or devonian, Dehrúd pass.—The oldest rock *in situ* appears

to be a calcareous sandstone of dark grey to purple colour, with an indurated limestone which contains some few fossils, amongst which a Productus and Orthis (?) seem the commonest forms. The beds dip to the north about 35° to 40°, and are conformably overlaid by Productus-limestone of the carboniferous system both on the north and south side of the pass, and the latter by hardened greenish-grey shales and interstratified trap (melaphyre).

Binalut range.—I crossed afterwards the Binalut range further to the north-west, from Madán to Chinaran, but the route proved more or less useless to me, as it winds in and out of a wide depression in the range, along which nothing older than cretaceous rocks are exposed.

Yaktán range.—In a line south-east of the Binalut range is a lofty chain of hills, which on our old maps is named the Yaktán range, a name which seems unknown in that part of Persia. The high peak at the south-east termination of the chain is called the Bezd hill. When I visited it in March, I crossed it twice, but it was still thickly covered with snow, and consequently I had to keep near the lower slopes and the passes, where little of the rocks in situ is found. I was however able to make out the structure of the range, which is similar to the Binalut range, inasmuch as it is formed of a high anticlinal fold of carboniferous rocks, flanked by the permo-triassic plant-bearing series. The carboniferous rocks consist of solid grey (mostly very dark) limestones in beds of one to two feet thick containing many characteristic carboniferous fossils, corals and Brachiopods. Iron pyrites and small nests of antimony are found in many places in the range; the latter is extracted near Rawand and used by the natives. The plant-bearing series, consisting of green and grey shales with sandstone and conglomerate, appears to rest quite conformable on the older rocks.

Doshakh range.—Continuing the strike of the Yaktán range, one reaches the Doshakh peak, on whose north flank I found again carboniferous rocks. The Doshakh range assumes a more west-east to north-east strike, and is in a line with the Davéndar range east of Herat. The north flank of both ranges consist of carboniferous rocks overlaid by the plant-bearing series, and the whole appears to have formed an anticlinal fold, the southern half of which has subsided along a line of fault, which has now brought cretaceous limestones in close and abrupt contact with the palæozoic rocks. This feature is well seen at the north foot of the Doshakh peak itself and in the hills north of Pahri, where hippuritic limestone is faulted against carboniferous limestone with Producti, &c. It will thus be seen that the structure of these four ranges is precisely the same, and that they must therefore be considered as belonging to the same system. The Doshakh, Yaktán and Binalut ranges form part of the great Central Asian watershed, and it would have been of the highest importance to follow up the continuation of this line to the east into the ranges which form the upper Hari Rud valley; it is a matter of regret to me that I was not allowed to avail myself of the opportunity offered by the presence in this part of the world of a mission composed of British officers, to carry out my researches to a legitimate end.

The minor ridges on the north side of the Doshakh range, including the Robat-i-Pai peak, are composed mainly of a great thickness of carboniferous beds which have an average dip to the north-west.

I ascended the stream which flows from the foot of the Doshakh peak more or less in a north-westerly direction and which irrigates a considerable extent of land near the village of Kashmarú. I found in descending order :—

4. Near Kashmarú hard reddish-grey sandstone, somewhat resembling the Chunar (Vindhyan) sandstones; regular flaggy beds, weathering dark-purple and black, and then resembling igneous rock from a distance. Dip 40° north-west.

3. Grey splintery and hard shales with ferruginous partings and irregular beds of hard dark limestone. No fossils. Several hundred feet thickness, weathers greenish-grey with brown ferruginous spots. Jointed; dip 50° north-west.

2. Impure earthy limestone of dark colour, overlaid by hard grey calcareous sandstone in thick beds. Dip 70° north-west. The limestone contains many fossils, mostly Brachiopods, *Athyris roissyi*, *Productus* sp. &c.

1. Near the Doshakh ziarat. Black or dark-grey very friable shales, alternating with ferruginous impure limestone breaking into jointed fragments; the limestone weathers a brown rusty colour. A few Brachiopod remains, badly preserved. Dip 60° north-west-by-north.

The beds of this series are here, near the foot of the Doshakh peak, faulted against the upper cretaceous limestone, which composes the peak itself.

Along the line of fault, which is nearly from east to west, the Zinjatak valley and pass has been scooped out by denudation. Some igneous rocks (melaphyres) have protruded along the fault, and have greatly obscured the actual contact of the palæozoic with the cretaceous series.

Chillingkhak pass.—The pass over which the road from Pahre to Zindijan leads, and which seems known as the Chillingkhak, exposes a similar section to the above. A few miles north of Pahre the cretaceous series abruptly ends, and the fault already noticed at the Doshakh brings the carboniferous rocks in close contact with the hippuritic limestone of the Pahre hills. The carboniferous system consists here of a great thickness (probably 2,000 feet) of hard dark-grey limestones, sandstones and splintery calcareous shales with many traces of Producti, Fenestella, &c. The beds dip to the north, at 30° to 40°, below the recent fan deposits of the Hari Rud valley.

Robat-i-Pai, in the Doshakh range.—A ravine runs in a northerly direction through the spurs which jut out from the group of high peaks known as the Robat-i-Pai. At the head of the ravine is the ancient and celebrated shrine of the "Sacred feet." I may here mention that the depressions on the waterworn sides of the ravine, which (with a little artificial help perhaps) resemble somewhat the shape of gigantic human foot-marks, are nothing else but water-worn hollows in the rock, of the same nature as are the well-known pot-holes. Some years ago a deadly strife originated when some devotees of Mashhad nearly succeeded in carrying off these sacred marks. Several had already been removed by carefully under-cutting and chipping off of the block on which the marks existed, when the perpetrators of the deed were caught in the act,—and of course met their reward. The entire mass of the Robat-i-Pai peaks consists of thick even beds of hard dark-blue limestone with calcspar veins, with some hard grey sandstone, both of which contain many carboniferous fossils. I recognised amongst them *Productus semireticulatus*, *Athyris roissyi*, *Fenestella*, and other carboniferous

fossils. The beds dip 50° to 75° north, below the recent deposits of the Hari Rud valley.

Davéndar range.—The Davéndar range consists of the main ridge, rising to over 11,000 feet in height in one or two peaks, with outer parallel ridges, the whole forming an anticlinal arch, the lowest beds of which are found not in the main range but in the auxiliary range north of the Davéndar, running parallel with the latter, and in which the Sang-i-Ajal and Kholi Biaz are situated.

I crossed this outer range between Jaúzá and Naorozabad near the Kholi Biaz hill, and found the latter to consist of carboniferous strata, represented by hard, dark, splintery limestone, containing many Producti, Fenestellæ, Crinoids, &c., characteristic of the carboniferous limestone of the Himalaya. Not much of these beds is exposed; both flanks of the Kholi Biaz, with the Davéndar range to the south of it, consisting of younger strata, belonging to the plant-bearing series (permo-trias) which I shall describe below.

Igneous rocks of the older palæozoic.—Igneous rocks are found in the neighbourhood of all the carboniferous localities which I described, but they belong most probably to the upper jurassic epoch, during which enormous outpourings of melaphyre took place. Only in the carboniferous series of the Dehrúd pass of the Binalut range have I found trap apparently interstratified with Productus-limestone.

The permo-trias and jurassic formations.—Towards the close of the carboniferous period a change of physical conditions seems to have occurred in the entire Central Asian area. The beds which rest in all the sections of the Herat province and Khorassan upon the upper carboniferous rocks, consist of deposits such as are formed near a coast line and near the estuaries of great rivers, namely conglomerates, sandstones and shales, which not only contain marine fossils but also plant-remains. In several sections which I examined I found great thicknesses of plant-bearing sandstones, probably deposited near or in the estuaries of rivers, alternating with irregular deposits of massive limestones containing many marine fossils. I believe therefore that the present watershed of the Binalut-Yaktán-Doshakh ranges, south of which I have not found any beds of this plant-bearing series, also marks more or less the old permo-trias coast line.

From the observations of Blanford,[1] Grewingk,[2] H. v. Abich,[3] and others, it appears certain that the same beds occupy large areas in the Elburz range, and in the Armenian provinces of Asia Minor. From Mushketoff's researches in Central Asia it also appears that the same group of strata are found over a large area in Russian Turkomania, near Tashkend, Samarkand, &c.

I found beds belonging to the plant-bearing system on the flanks of the Binalut, the Yaktán, Doshakh and Davéndar ranges, and the Paropamisus, Estoi and Jam ranges are almost entirely made up of rocks belonging to the series. It would be of the highest importance to trace these littoral formations eastwards until a junction could be effected with the Himalayan marine beds of the same age.

[1] East Persia, Vol. II, by W. T. Blanford. London, 1876.
[2] Grewingk: die geogn. und orogr. Verhaltn. d. nordl. Persiens, 1853.
[3] Vergl. geogn. Grundzüge, &c.

The system is capable of being divided into the following groups:—

Overlying Cretaceous beds.

TITHONIAN . . .	Light-coloured sandstones and grits with plants; marine beds with fossils.
UPPER JURASSIC . .	Red grit group.
LOWER JURASSIC AND LIAS . . .	Marine limestone. Green sandstone with Gondwana plants. Limestone with Brachiopods.
RHÆTIC TRIAS AND PERMIAN . .	Limestone with Brachiopods. Sandstones, conglomerates and green plant shales.

Underlying Carboniferous limestone.

1. *The plant-bearing system in Afghanistan.*

In describing the carboniferous of the Davéndar I have mentioned that the auxiliary range north of and parallel to the Davéndar is partly composed (near the Kholi Biaz and Sang-i-Ajal) of carboniferous limestone. This is overlaid on each side by younger rocks, belonging to the plant-bearing series, and by great outbursts of igneous rocks (mostly melaphyres) belonging to the upper jurassic group.

The section on the north slope of the pass between the Sang-i-Ajal and Kholi Biaz is in natural order and very clear. It is in descending order.

14. Red grit group with igneous rocks. From about 4 to 5 miles south of Naorozabad, extending over the greater part of the valley of the Kurukh stream towards the north, red grits with purple and greenish conglomerate, volcanic breccia and tufa, and a dark trap rock are in situ, deeply eroded into ravines by the streams draining into the Kurukh river. The dip is variable, but on the south side of the valley is chiefly to the north and north-west.

13. Sandstone and hard flinty limestone, alternating with red grit beds,—dip about 30°, west to north-west.

12. Red sandstone and grit with grey sandstone, entirely composed of material derived from the older igneous rocks.

11. Limestone breccia and conglomerate, with limestone beds (traces of fossils). The fragments of the breccia are chiefly made up of carboniferous rocks and trap.

10. Great thickness of greenish-grey, very friable shales, with traces of plants.

9. Soft sandstone bed, a few feet thick, of olive green colour, enclosing reed stems; with irregular thin-bedded shaly sandstone, containing Vertebraria (?)

8. *A thin coal-bed,*—about 1 inch in thickness.

7. Gritty sandstone with pebbles, chiefly of limestone.

6. Green shales interstratified with sandstone.

5. Green sandy micaceous shales, with coaly particles and some plant impressions.

4. Thin bed of greenish-grey fine grit, or coarse sandstone, weathers brown.

3. Grit, with limestone fragments of the carboniferous group, containing fossils.

2. Hard altered sandstone of felsitic character with shaly beds (phyllite), of considerable thickness, alternating with gritty beds.

1. Hard dark-grey to black limestone in regular beds, containing in the upper strata numerous crinoidal stems and fragments; also many Brachiopod remains; *carboniferous (upper).*

The Sang-i-Ajal and Kholi Biaz hills are entirely made up of beds belonging to the carboniferous group, dipping about 65° north, on the north slope of the Kholi Biaz, and nearly vertical at the southern base of the pass leading over that range. The plant-bearing beds resting on the carboniferous group are quite conformable to the latter, and the dip gradually lessens towards the centre of the Kurukh valley.

The southern portion of the Davéndar section differs in some respects from the Kholi Biaz succession. Descending from Jauza Killah to the pass just described, I observed the following beds,—in descending order:—

7. Igneous rocks (melaphyre) associated with the red grit group; dip about 30 to 40° south to south-west. The red grit group forms all the lower spurs which extend from the Jauza H. T. S. towards the junction of the Kurukh and Herat rivers, and may be observed to form also the Jauza hill with the lower slopes of it. The dip is rather rolling, but in the main to the south-west. Thick red sandstone with grit and conglomerates, and a few thin beds of micaceous shales (red) are interstratified and *laterally* replaced by igneous rocks (melaphyre). Some of the most conspicuous points and nearly all the craggy hills in the ranges are composed of the trap. The Jauza hill (over 11,000 feet) is almost entirely made up of a dark augitic rock.

6. Near the centre of the great anticlinal, or rather dome, of the Jauza section, I came upon an impure reddish-grey hard limestone, with brecciated beds. The limestone is in parts oolitic in structure; I noticed a few traces of fossils (Brachiopods) north of Jauza Killah, but could not get them out of the rock. The beds of limestone are apparently not very regular, though I always found them near, or immediately below, the red grit beds. North of Jauza village, in the stream which runs into the Kurukh river near the village of Kurukh, the limestone beds are again seen just below the red grit series, and at that locality I found some well preserved Brachiopods, of a rhætic or liassic character. The bed is evidently of very varying thickness, for on the north slope of the Zurmust I met it in very considerable development. Immediately below it I met—

5. Calcareous grit and breccia with green shales (phyllites) containing angular fragments of igneous rocks.

4. Reddish and green shales with leafy impure limestone, traversed by innumerable veins and joints filled with calcspar.

3. Greenish micaceous shales (phyllites); considerable thickness.
2. Felsitic rock with imbedded trap.
1. Limestone, conglomerate and grit.

The lower beds of this section, from 1 to 6, comprise the greater part of the section seen on the north side of the Kholi Biaz hill, beds 3 to 11. This group of beds has probably been deposited near a shallow coast, and both the lower (permo-trias) andthe middle section (jurassic) of the series attain a much greater thickness further north and north-west, and in Khorassan attain enormous thicknesses.

The centre of the anticlinal which forms the Davéndar range is therefore not to be found in the main range, but north of it, and is marked by the Malúma stream valley, where the older (carboniferous) rocks are exposed.

The Kurukh valley, from near the point where the stream leaves the hills before entering the Herat valley, to many miles east of the Davéndar hills is formed chiefly by the red grit group.

The Paropamisus range, bounding the valley on its north side, also forms an anticlinal, considerably disturbed by minor faults, and in some places the beds are so crushed as to leave great doubts concerning their relative position. Fortunately I was able to go over the Zurmust section a second time and thus satisfy myself about the correct interpretation of the structure of the range.

The red grit group with its igneous rocks forms a great trough, in which the Kurukh stream has eroded a deep channel. On the left side of the valley the beds forming the group dip nearly north, whereas in the Zurmust range the red grit group and interbedded melaphyre dip at an angle of 65° to 70° to the south-east.

The entrance to the Zurmust is occupied by a purple and red grit, which in places becomes quite a conglomerate, extremely hard, and seems to have been subjected to alteration near the contact with the trap. From that point to the height of the Zurmust pass there is an alternation of grits, red shales, volcanic tufa and melaphyre, with an amygdaloid rock.

The igneous rocks assume much greater thickness towards the east, the upper Kurukh.

Tithonian.—North of the Zurmust pass, and in the range over which the Kashka Kotal leads to Naratú, the red grit group is seen to underlie a group composed of white sandstones and grits with plant-remains, and interstratified limestones containing marine fossils.

I had no further opportunity this year of revisiting the Naratú-Kilnaú section which I have already described in my last notes. But from observations of rocks further west it appears certain to me that the Naratú plant sandstones, overlying the red grit group, belong to the tithonian horizon and form a passage from the upper jurassic into the neocomian limestones and marls which are seen between Chakan and Kilanaú, on the road to Bala Murghab.

Marbich and Band-i-Baba.—The Paropamisus between the Zurmust pass and the Marbich shows nearly the same structure as I observed in the Zurmust section, but although the general feature of the range is that of a great anticlinal or anticlinals, it has undergone such great disturbances, and the beds composing

it are so much shattered, that the true succession of strata could hardly be made out anywhere between these points, if the neighbouring region had not afforded a key for its interpretation.

Fault of the Paropamisus.—Between the Band-i-Baba and the Zurmust it may easily be seen that a line of fault runs east and west, south of the main range; and beds of the middle of the plant series (the red grit group) are thrown against and partly thrust over some of the white sandstones and grits of the uppermost group (tithonian). Near the Thagan Robat, north of the Zurmust pass, the fault has thrust the red grit group partly over the younger white sandstone (tithonian).

Near the Marbich pass the fault crosses to the north side of the Paropamisus, crushes beds of the red grit group against upper cretaceous, and is lost further west below the tertiary deposits of Badghis. In the Estoi range, in Khorassan, the fault appears again plainly, and may be traced in a more or less north-westerly direction along the Kat-i-Shamshir hills. The hot spring of Garm-ab (115° F.), north of Tiraman, rises along this fault.

The Band-i-Baba.—The main range, over which the Band-i-Baba pass leads from Kushk is composed of the uppermost group of the jurassic series, represented by light-coloured sandstones and grits with intercalated limestone with marine fossils. The same beds are seen in the Kashka Kotal, north of the Thagan Robat, and at Naratú, and I believe represent as nearly as possible the tithonian stage of Europe. I found in descending order:

Tithonian . . {

1. Sandstone, dark grey, fine-grained, with numerous Ostrea remains and calcareous beds entirely composed of an Ostrea species.
2. Sandstone, light grey, with greyish-white sandy shales; the first contains some plant-remains; the latter a few bivalves. The dip is rolling, but generally to the north.
3. Sandstone and grit with zones of conglomerate. Resembles strongly upper Gondwaona sandstone and contains plant-remains.

The series may be seen in all the ravines which lead towards the Marbich and Band-i-Baba from the grassy slopes of the Kushk valley, and the beds dip under an angle of about 25° to 30° to the north.

South of the pass I found that beds belonging to the red grit group are faulted against the mass of light-coloured grits of the Band-i-Baba, and the strata composing the upper jurassic are dipping 25° to the south. Near the actual contact great disturbance and crushing is noticeable, the beds of the red grit group being here and there raised up vertically and even inverted. Between the top of the Band-i-Baba and the ravine south of Robat-i-Khona, leading to Palezkar, the red grit group is as follows in descending order:—

Red-grit group . {

3. Hard bluish-green sandstone, forming very thick beds with grit zones and trap pebbles. The sandstone is composed of volcanic material

Red-grit group .
2. Breccia, same as 1, but in thinner beds, alternating with a clay shale or concretionary clay of dark green or red colour; this group is of great thickness, and can hardly be less than 1,200 to 1,500 feet.
1. Dark brownish-red and purple conglomerates and grits the fragments made up of igneous material, alternating with great layers of trap breccia and volcanic tufa. The fragments are all derived from igneous rocks, generally melaphyre, cemented by a black or dark-green tufaceous matrix. Interstratified with red grits and sandstones.

Palezkar beds, Talchirs ?—The low hilly ground between the hills immediately north of Herat and the foot of the Band-i-Baba range itself, is formed by a synclinal, much disturbed and in some places completely crushed. Between the village of Palezkar and Robat-i-Surkh, in the Herat valley, some of the lower beds of the plant-bearing series are exposed. They consist of a group of sandstones and green shales, associated with interstratified trap (amygdaloid melaphyre), which may be seen well exposed near the high conical hill known as the Hissar-i-Ghulamán, and in the ravines of the Palezkar and Shorán streams, which drain into the Kurukh river.

Nearer Robat-i-Surkh, I noticed a greenish-grey impure shale, micaceous, with traces of plant-remains (Vertebraria ?) associated and alternating with conglomerate and a trap breccia in thick beds.

Towards the south-east they are overlaid by coarse brown sandstones and grits, with badly preserved plant impressions, and towards Muchkhandak by the red grit group.

Altogether the Palezkar beds resemble in some respects the Talchirs of India, and still more so the lower (Ecca) beds of the Karoo formation of South Africa, and recall to me vividly the sections seen a few miles south of Pietermaritzburg in Natal, and the beds exposed in the ravines of Kleine Karoo and the Bokkeveld of the Cape.

I believe they belong to the beds 2 to 7 which I described as overlying conformably the carboniferous limestone of the Kholi Biaz hill, in the Davéndar range, and form most probably a passage from the upper carboniferous into the trias, comprising perhaps the upper Kuling beds of Himalayas with *Otoceras woodwardi.*

Hills north of Herat.—The hill range which runs almost east to west, and within 2 miles of Herat, is composed of several groups of rocks, which form three separate zones. The greater part of the range, from a point half way between Parwana and Herat to Robat-i-Surkh, is formed by the older beds of the plant-bearing system, which dip to the north-east, and apparently rest on hard grey splintery limestone, which forms the range between the Parwana stream and the Sinjao valley, and which may be carboniferous.

I crossed the Paropamisus between the Band-i-Baba and the Hari Rud by the Ardewan, Chasma Sabz and Robat-i-Surkh passes, and partly explored the Marbich route.

Marbich and Koh-i-Kaitu.—The latter route skirts both the Koh-i-Kaitu and Marbich peaks, which, in their general features, resemble the Band-i-Baba. The southern half with the Koh-i-Kaitu is composed of the red-grit group which is faulted against the tithonian grits and Ostrea limestones of the Marbich.

Ardewan.—The beds composing the Ardewan all belong to the red-grit group with a part of the higher tithonian white sandstones and grits overlying it. The structure presents one or more folds, with a considerable amount of local disturbance. North of the pass, where the road enters the grassy slopes of the Kushk drainage, the sandstones of the tithonian group have been faulted and crushed against beds (white marly limestone) of the upper cretaceous formation. I believe this to be on the same line of fault which I could trace from point to point through the Paropamisus and the Jam hills of Khorassan.

The rocks, which compose the red-grit group of the Ardewan, consist of thick beds of grit, sandstone and conglomerate, mostly of a dense reddish-brown to purple colour, in general character resembling the rocks of this group at the Zurmust pass. The conglomerate changes locally into a volcanic breccia, which is well shown in the cliffs just north of Kush Robat, near the south entrance to the pass. I found no trap *in situ*, but thick beds of volcanic ash, with embedded bombs of malaphyre, are intercalated between the conglomerates. The general dip of the group varies from north-west to north-east, but in one or two places small folds repeat the series of beds.

Beyond the watershed of the Sinjao stream and the stream which drains into the Kushk, the red-grit group is overlaid conformably by coarse sandstones (with ferruginous nodules) and grits with calcareous beds, containing marine shells, which I believe to belong to the tithonian horizon, continuous with rocks of the same age of the Marbich, Band-i-Baba, and Kashka Kotals. The sandstone is cut off by the fault already noticed, and crushed against upper cretaceous limestone with *Inoceramus cripsi*, Mant.

Chasma Sabz pass.—The section exposed at the Chasma Sabz pass is almost identically the same as the one seen in the Ardewan. It consists of a series of beds of the red-grit group, dipping 15° to 20° north-east, and in descending order I found:

4. Densely red grits and ferruginous sandstone, forming a lower and parallel range north of the Chasma Sabz pass.
3. Grey friable needle shales, conglomerates and partings of clay shales.
2. Grits and greyish needle shales with bluish-grey hard clay shales.
1. Red and brown to purple sandstone with coarse conglomerate and volcanic ash beds.

2. *The plant-bearing system in Khorassan.*

The Gaúkharchang pass and the Kat-i-Shamshir range.—The great fault described on page 56, and which runs more or less south-east to north-west through the Paropamisus, divides also the range of hills which bears the name of the Kat-i-Shamshir on our old maps. Here the fault runs close along the north side of the watershed between the Jam river valley and the drainage which falls lower down into the Hari Rud. The fault is well exposed in the Gaúkharchang pass

itself, and further to the north-west at the hot spring of Garm-ab (115°F.), it is lost amidst the tremendously crushed strata.

The southern half of the Gaúkharchang pass, which leads from the Jam valley north of Turbat-i-Sheikh-Jam to Zohrabad, is composed of fragments of sandstones and grits belonging to the red-grit group with great masses of igneous rocks. The prevailing rock is a melaphyre, with long strips of a syenitic granite, which I believe to belong to a later epoch. Ash beds and volcanic conglomerates are found between the enormous layers of bedded melaphyre, dipping gently to the south below the late tertiary deposits of the Jam valley.

The northern half of the pass between the fault and the Zohrabad plateau, past the Burj-Kalich-Khan, is formed chiefly by beds belonging to the middle and upper groups of the jurassic system. The structure is that of one or more anticlinal arches, somewhat crushed here and there, but sufficiently clear to establish the following groups in descending order:

Tithonian . .	3. Light-coloured sandstone, grit and limestone beds; the latter with Ostrea sp.
Red-grit group, upper jurassic.	2. Dark-grey to black finely bedded shales, very friable, with ferruginous partings. Great thickness. Fragments of plant-remains. Coarse red grit and sandstone in thick beds.
Lower and middle jurassic.	1. Greenish-grey coarse sandstone with ferruginous partings, and dark-grey, fine needle shales. The grey shales show some badly preserved plant-impressions, but the sandstone (near Burj-Kalich Khan) yielded a great number of both marine lower jurassic fossils, Brachiopods, Bivalves, Echinoderms, &c., and also of remains of *Glossopteris* sp., and other Gondwana plants in a fairly good state of preservation.

It is remarkable how the red-grit group and the higher grits of the tithonian have dwindled down in thickness in this section, compared to the great deposits of sandstone and volcanic ash beds which form this group in the Paropamisus sections. The stream of Paídáh Ján Murád, north-east of the Burj Kalich Khan, has formed picturesque escarpments in the red-grit group, resembling greatly the escarpments in the Mahadeva sandstones of Sirguja and Palamow in India.

Robat-i-Surkh pass.—Approaching the Robat-i-Surkh pass from the north (Gulrán), one has to pass over rolling hills of rounded outlines, composed, as far as I could judge from the scanty exposures seen *en route*, of nothing else but the soft argillaceous beds and soft sandstones which I believe belong to the upper Siwalik horizon. Near the north slope of the pass a number of low spurs are seen to run out from the Mash range, and I found them to consist of light-brown sandstones and grits in thick beds, which resemble the plant-bearing sandstones of the Band-i-Baba. The beds dip here gently to the north below the Gulrán beds.

The pass itself shows a group of sandstones, generally thick-bedded, which in

its upper portions is alternating with reddish and greenish marly beds. I found no fossils in any of the strata, but I believe the whole to belong to the red-grit group, which it closely resembles.

The structure seems to be that of a wide anticlinal curve; the pass itself is formed by simple erosion of two streams, flowing north and south, separated by a low watershed of only a few hundred feet in width.

Further to the north-west, the red-grit group swells again in thickness, and on the left side of the Kashaf Rud valley forms all the lower slopes underlying the cretaceous rocks of the Takht-i-Gauzak.

The pass, which leads from Sang-i-Safed (near Firaiman) over to Kat-i-Shamshi to Garm-ab, reveals a section very like the one traversed by the Gaúkharchang pass. The beds of the red-grit group, which compose the entire range at this point, are much shattered and folded. Near the south entrance to the pass, the beds dip to the south-west and are overlaid uncomformably by younger tertiaries, conglomerates, and sandstone. The red-grit group of this pass consists of densely red conglomerates, grits and volcanic ash beds with trap interstratified, between the layers of which irregular beds of grit often appear. There are also some earthy black shales associated with the grit, and several irregular masses of hard splintery grey sandstone, traversed by numerous calcspar veins. The lower strata of the red-grit group resemble the beds seen on the north slope of the Jauza hill in the Davéudar section; immediately below the grit I found a greenish-grey concretionary shaly sandstone which overlies a fine-grained, hard greenish-grey and reddish-grey sandstone similar to the one which I met in the Jauza section, south of the Kholi Biaz.

Near Garm-ab, on the north side of the pass, I found the bedding much disturbed, and near the fault much shattered. Near Kummer Sard, a small settlement of Nomads north-west of Garm-ab, I saw the red-grit group conformably overlying the lower jurassic black plant shales.

Between Bareili and the Takht-i-Gauzak.—The trough between the Bareili hill, the highest part of the Kat-i-Shamshir range, and the Takht-i-Gauzak, south-west of Pul-i-Khatun, is formed by a succession of folds composed of lower and upper jurassic rocks. The former are developed as black or dark-grey shales with greenish-grey sandstones, which yield lower jurassic marine shells and some Gondwana species of plants. They are overlaid by the red-grit group which dips below the tithonian and lower cretaceous of the Takht-i-Gauzak.

The country between the two ranges is more or less uninhabited now, and water is only obtainable at a few points. I had therefore to hurry over it too quickly to make very detailed observations.

The plant-bearing system in the Yaktan range and Bizd hill.—The Yaktán range runs in a north-west south-east direction between the Jami and Shahr-i-Nao valleys, and forms a continuation of the Binalut range. At its south-eastern extremity is the Bizd hill, south-west of Turbat-i-Sheikh-Jami. As already described, the range is formed by a steep anticlinal fold, the centre of which is composed of carboniferous marine limestones, overlaid on each flank by beds belonging to the plant-bearing system. When I examined the range in March of this year, the greater part of it was still covered with thick masses of snow, and only at one

locality (near Raband) was I able to penetrate the outer hills to the inner core of carboniferous limestone. The depression between the latter and the outer hills was then almost filled by snow, so that I have not been able to see either the contact between the two systems of formations, nor the lower beds of the plant-bearing series.

The Bizd hill itself is composed of igneous rocks (melaphyres) with sandstone and conglomerates of the red-grit group of precisely the same lithological character as noticed in the sections of the Paropamisus.

The same rocks with great deposits of volcanic ash beds and tufa are seen all along the northern slope of the Yaktán range. The beds of conglomerate and sandstone with interstratified igneous rocks dip to the north-west, and apparently are conformable to the carboniferous limestone which form the main range, but the actual contact I have not seen.

Plant beds of Kalanderabad.—Near Kalanderabad the outer range separates into a chain of isolated low hills, which consist of a hard, light-grey, splintery limestone, overlaid by plant-bearing beds. I remember having observed a similar bed of grey splintery limestone in the plant-beds of Palezkar, near Herat.

The Kishti Pukhta pass from Kila-i-Nao to Amun-Jaffre (and Aliyek).—The rocks composing the parallel ridges of the pass which leads over the Yaktán range, belong nearly all to the plant-bearing series with its igneous rocks.

Near the northern side of the pass (near Kalanderabad), I observed greenish-brown sandstones, with shaly partings, dipping 50° west. They yielded a few poor specimens of plants, the common reed-like fragments.

The series of beds is contorted, and forms a synclinal near the centre of the pass. The structure is too complicated to allow a careful survey during a hasty march, but I noticed the close connection of igneous rocks with the plant-bearing sandstones and conglomerates. The igneous rocks are chiefly melaphyres with a red felspathic rock, very common in the red grit group. With it occurs a volcanic breccia, containing some rolled boulders of large sizes, embedded in a porous volcanic tufa, with angular fragments of igneous rocks.

The sedimentary rocks of the group form narrow strips within the belt of igneous rocks, and are, with few exceptions, all sandstones of reddish-brown and greenish colour. Some high cliffs on the left side of the valley, near the Kilah-i-Nao entrance to the Kishti Pukhta pass, are composed of a great thickness, of a coarse brown sandstone, with grit partings, showing false bedding well marked. Several beds of a coarse conglomerate occur with it. In the lower layers I found a few irregular deposits of reddish-brown clay. A large deposit of irregular thickness of the boulder breccia, already described, I noticed at the base of the sandstone, forming the right side of the valley and overlaying the igneous rocks.

Another patch of sandstone, which reminded me of the Talchirs of India, I found near the south side of the pass, not far from Amun-Jaffre. It is a soft, olive-coloured sandstone, with small ferruginous concretions in some of the strata and partings of olive-green shales. I found no fossils in them. Near the southern side of the watershed I found an irregular thick bed of white limestone of a fine crystalline texture, very hard and splintery, enclosed in the igneous rocks of the group, and apparently belonging to it.

Karat range.—The range which separates the Khaf plain from the Shahr-i-Nau valley, and which bears the name of the Karat range on our maps, I have unfortunately not visited, but from the distance it appears that the higher range with the peak Koh-i-Khaf is composed of a dark rock, presumably limestone, dipping to the south at a low angle.

North to north-west of it, I noticed other rocks, of a lighter brownish-green colour, dipping gently towards the Khaf range. This latter rock I believe to be the group of igneous rocks, shales and sandstone of the plant-beds.

Binalut range.—The Binalut range is similar in structure to the Yaktán hills, and is in fact only a continuation of the latter. Only in the Dehrud pass section did I cross the plant-bearing series, which north of the Dehrud pass itself, between it and the village of Golistán, overlies conformably the carboniferous limestone with marine fossils.

The plant-bearing group is here represented by hard grey and green shales associated with volcanic ash beds and a variety of eruptive rocks. I found no fossils in the shales.

Red-grit group of Madán.—North-west of Nishapur, the ancient capital of Khorassan, some spurs branch off the Binalut range which seem all to belong to rocks of the red-grit group of precisely the same lithological character as those seen in the hills east of the Band-i-Zurmust.

The Madán hill itself is composed of volcanic ash belonging to the group, with some contact rock, which will have to be carefully analysed hereafter. In this contact rock the celebrated turquoises are found, and there are now about a thousand "mines" in and around the hill, of which about a hundred only are worked; the best stones are found in pits sunk in the mountain talus, where of course the mineral is easily extracted from the crumbling decomposed mass.

The extraction from the surrounding matrix seems the difficulty in obtaining good and large stones, which otherwise abound in great quantities.

Unfortunately the hill mass of Madán is so completely enshrouded on all sides by recent tertiary deposits, that I have been unable to trace the actual connection of the rock composing it with the lower plant-bearing series of the Binalut range.

The rhætic and jurassic deposits of the Kelat-i-Nadri section,—The section between Mashhad and Khelat-i-Nadri is one of the most interesting in Khorassan. There the entire series from the rhætic to the upper cretaceous is represented by marine beds.

A stream, running almost due north-south, has eroded a deep and very narrow gorge through the hard limestones of the upper rhætic and jurassic series; in some places so narrow that there is only room for a laden mule to pass through. The Arka-bun-Shah pass leads into the gorge excavated by the Kelat stream, running north, which has eroded a similar gorge through a succession of limestones and hard shales.

The section is an extremely good one and presents a succession of folds mainly composed of hard splintery limestones and dolomites with some shaly partings, which in several horizons yielded fossils, chiefly Brachiopods, belonging to the upper rhætic or lower lias. The upper beds contain a few sandstone part-

ings, and yielded, besides marine fossils, some rather badly preserved plant-remains. These beds, which I believe to be lower jurassic, are overlaid by massive limestones (with corals) and red grits, somewhat resembling the red-grit group rocks. This marine system is conformably overlaid by the cretaceous rocks of Kelat-i-Nadri.

The cretaceous rocks of the Herat province.

In the Herat valley itself, I have not met with any cretaceous rocks, but the southern half of the Doshakh range, with the peak itself, belongs to the wide-spread hippuritic formation, which forms nearly all the hill ranges of South and Western Afghanistan. The Zingaták pass from Kashmarú to Pahri marks approximately a fault which has brought the palæozoic rocks of the northern half of the Doshakh range with the Robat-i-Pai peak in direct contact with hard white and grey coral limestone, which yielded many hippurites, some badly preserved ammonites and bivalves.

I have nothing to add to my description of the cretaceous rocks of the Tirband-i-Turkestan, which I have not been able to revisit.

Cretaceous rocks north of the Paropamisus.—North of the Ardewan pass, crushed against the upper jurassic or tithonian sandstones and grits, I met white marly limestones, which contain *Inoceramus cripsi* Mant. in excellent preservation, a species common in the upper cretaceous formation of Hungary and South-Eastern Europe.

The cretaceous system occupies a large area north of the Estoi and Paropamisus range, and I found the upper horizon with *Inoceramus cripsi* in almost all the sections which I have seen of the cretaceous beds of that region. Most probably the shell limestones of Kushk, of Chakan, and the greater part of the Tirband, belong to the same system

The cretaceous rocks of Khorassan.

Cretaceous beds may be traced from Khelat-i-Nadri in a south-east direction to the range of the Takht-i-Ganzak and the cliffs of the Hari Rud between Pul-i-Khatun and Zolfikar. Most of the ground north of the Estoi hills to the Kashaf Rud valley is also covered by beds belonging to the cretaceous system.

I found that the system, which cannot be less than about 3,500 to 4,000 feet in thickness, can be divided into—

Upper cretaceous .	4. Earthy brownish-white limestones, with flaggy beds of white limestones. Forms high cliffs along the Hari Rud, Kelat-i-Nadri, &c. Yielded many cretaceous fossils, amongst them *Inoceramus cripsi* Mant.
Lower cretaceous .	3. White earthy limestones and chalk with indurated clay; fossils in bad state of preservation. 2. Dark shales, with ferruginous partings. 1. Yellowish-white earthy limestones, many well-preserved fossils,—Brachiopods, Trigonia, &c.

Between Kelat-i-Nadri and Zolfikar this section may be seen at any point, and the beds seem hardly disturbed at all, generally sloping gently to the north-east, showing steep scarps towards the south and south-west.

The cliffs along the Hari Rud, between Pul-i-Khatun and Zolfikar, are entirely formed by these rocks and offer complete and undisturbed sections.

The massif of Kelat-i-Nadri is a synclinal basin formed of cretaceous rocks, through which the Kelat treams has eroded a transverse valley, or rather gorge.

Cretaceous rocks in the Binalut range.—Limestones with some fossil remains which I found dipping below nummulitic beds near Sultan Maidan, in the Binalut range, probably belong to the cretaceous system.

Granite and gneissose rocks of Herat cretaceous.—Immediately north of Herat, from a point nearly north-west of the city to north-east, including the low hills of Ghazegah, a gneissose rock with syenitic granite dykes is found, which seems identical with similar rocks of the Upper Kurukh valley and the Davéndar peak itself. This belt of granitic and gneissose rocks may be traced along the south slope of the Estoi hills (in the Gaúkharchang pass) to Sangbast, south-east of Mashhad, and I believe belongs to a period subsequent to the red-grit group, possibly to the same outburst which has converted so much of the upper cretaceous rocks of Southern Afghanistan into fine marble.

Nummulitic rocks.

Beds with nummulites, and associated with younger eruptive rocks, rhyolites and trachytes, I have only come across near Madán, north-west of Nishapur, in Khorassan. The nummulitic beds here occupy a large area, south of Madán; and on the Sultan Maidan, north of the turquoise mines, I found nummulites in a calcareous dark limestone and in sandy beds, closely associated with great masses of rhyolite, which has changed the sedimentary beds locally, and partly converted them into semi-metamorphic masses.

At the Sultan Maidan the nummulitic group seems to rest conformably on a grey shell limestone which I believe to be cretaceous, and which forms the western slope of the Binalut range, north of Madán.

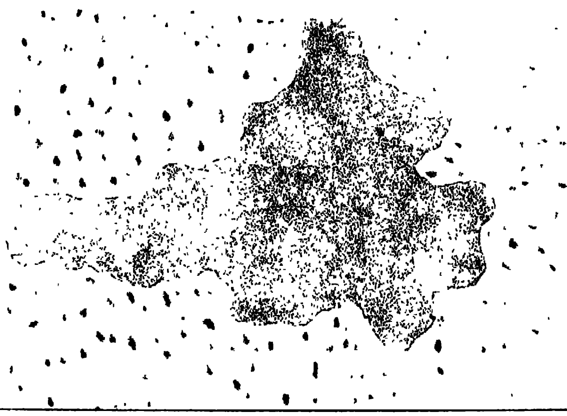
On the outer slopes of the Kat-i-Shamshir between Sang-Safed and Sangbast, south-east of Mashhad, I found the beds with nummulites in descending order:

Miocene or oligocene?	5. Red conglomerate and sandstones in thick beds, dip 28° to 30° west to south-west-by-west. 4. Conglomerate, consisting of nummulitic limestone pebbles.
Nummulitic	3. Grey shaly limestone with Brachiopods. 2. Yellowish-white limestone, corals, Ostrea, nummulites. 1. Dark-grey shales with intercalated concretionary limestone, which contains many bivalves, echinoderms, nummulites, &c.

The beds below this are obscured by recent deposits, but a few miles south-east of the locality cretaceous beds dip below the fan of recent accumulations of

Fig 1.

Fig. 2.



J Schaumburg, Lithd Printed at Geol Surv Office

clay and conglomerate and most probably would be found to conformably underlie the nummulitic group.

Miocene.—Miocene rocks seem to be widely distributed north of the Paropamisus and on the Sarakhs plain, but I have not myself been able to identify them. Captain Yate and Dr. Owen of the Afghan Boundary Commission have brought me well-preserved specimens of *Ostrea multicostata*, Desh.; the first from the Nimaksar, north-east of Zolfikar, and the latter from Khwaja Kallandar, north-east of Kushk, in Badghis. I have not been able to visit either of these localities. Apparently the fossils occur in a light-coloured clay associated with the salt-bearing and gypsiferous group, which is largely developed in Northern Badghis.

Younger tertiaries.—To the description of the younger tertiaries given in my last "notes" I have nothing to add of any importance. Good sections through the upper groups of the tertiary system are seldom met with, as they are generally hidden below enormously thick masses of alluvial deposits and fans.

CAMP, SHEIKH-I-WAN, HERAT VALLEY,
13th November 1885.

Notes on the Section *from* Simla *to* Wangtu, *and on the* petrological character *of the* Amphibolites *and* Quartz-Diorites *of the* Sutlej *valley; by* COLONEL C. A. McMAHON, F.G.S. (With a plate.)

Part I: Introduction; description of the section.
" II: Notes on the microscopical character of traps, amphibolites and quartz-diorites.
" III: Remarks on the character of the rocks, and on the stratigraphy of the region.

PART I.

INTRODUCTION.

A visit to Simla during 1884 afforded me an opportunity of taking a run up the Sutlej valley as far as Wangtu. The time at my disposal for the trip was however so extremely limited that I had to cover 22 marches in 8½ days, and travel at the average rate of 27 miles a day. But as I had been up and down the Sutlej valley on previous occasions, this rapid survey was sufficient to enable me to review my first impressions regarding the geology and stratigraphy of this region in the light of the experience subsequently acquired at Dalhousie and Chamba. I shall begin this paper with a brief sketch of the geology of the section from Simla to Wangtu by way of preface to my remarks on the petrological structure of the hornblende rocks and quartz-diorites of the Sutlej valley, and on the stratigraphy of this region.

The rocks between Simla and Narkanda have already been described by Mr. Medlicott in his Memoir[1] and referred to in the Manual of the Geology of India;[2] my first paper on Simla geology, also, contains notices of them.[3] A brief *résumé* of the lithology of this section will be given in the last part of this paper.

[1] Mem. Geol. Sur., Vol. III, pp. 38-40.
[2] Vol. II, pp. 603, 604.
[3] *Supra*, Vol. X, pp. 209, 211-214.

At Narkanda we have decided mica schists, dipping a little north of east, with beds of gneiss on the flank and top of Hattu, a mountain 10,469 feet high, that rises to an elevation of 1,600 feet above Narkanda.

Mica schists continue for some 3 or 4 miles on the road to Kotgarh, and are followed in ascending order by quartzites. There is a considerable thickness of the latter, but it would be impossible to calculate their precise thickness from roadside observations only, as the dip flattens and waves about in a somewhat unsteady manner as far as Kotgarh. The quartzites are followed by more or less micaceous rocks, and the dip finally settles down into a north-easterly direction. On leaving Kotgarh the metamorphism gradually declines, and dark rocks, with a micaceous glaze, succeed, which belong unmistakably to the infra-Krol carbonaceous series. The carbonaceous element in them is sufficiently strong to blacken the soil of cultivated fields here and there.

As the road from Kotgarh to Nirat (Nirth) nears the bottom of the valley, the gneissose granite crops up quite suddenly.[1] Where it first appears, the dip of its foliation is the reverse of the dip of the infra-Krol rocks, but it shortly afterwards reverts to the normal north-easterly dip. The actual contact of the two rocks is masked by vegetation.

The gneissose granite continues to Nirat, and thence to the Muchara river which flows from the east into the Sutlej to the north of Nirat. The Muchara appears, at this point, to mark the division between the gneissose granite and the carbonaceous infra-Krol rocks, which re-appear on its right bank dipping in a south-easterly direction.

So far as could be seen from the road, the Nirat outcrop of the gneissose granite exhibited a marked parallelism of structure that reminded me of the "outer band" at Dalhousie; but this outcrop strikes for, and doubtless merges into, the perfect granite of the Kot[2] peak north of Bargi. The outcrop is about 4 miles thick. The rock appeared to me to be jointed in the direction of the foliation rather than bedded. The lines of division are of unequal thickness, and are irregular and variable; they do not appear to persist for any great distance in the same direction, but merge into each other, or are stopped abruptly by other joints at right angles to their direction.

The infra-Krol rocks continue with a south-easterly dip as far as the Nogli,[3] a stream that flows into the Sutlej about 3 miles south of Rampur. The dip

[1] In my first paper (1877) I noted (*supra*, Vol. X, p 214) that the gneissose granite—then called gneiss—on its first appearance alternates with the carbonaceous slates. This I now think was an erroneous impression created by talus, or a land-slip, covering part of the granite. The blocks brought down, however, look like slates *in situ*, and it requires a good deal of consideration to detect the deception.

[2] Kot is not marked on the map. It is the point immediately to the north of the Garh Station, on the ridge running down from the Garh Station to the Sutlej, where another ridge joins it from the east.

[3] In my first paper already quoted (footnote *ante*) I stated that between Nirat and the Nogli the slates alternated with the gneiss. This mistake appears, as far as I can now make out, to have been owing to some misreading of my notes made 18 months previous to writing my paper. I marched along this road again in 1878 and noted no gneiss.

is sometimes very flat, and as the Nogli is neared, a northerly dip sets in for a short time.

The rocks are occasionally very silicious and almost jaspery, but are sometimes very dark, as at the village of Dantnugger. As the Nogli is neared, they are decidedly carbonaceous, and there is no doubt about their belonging to the infra-Krol series.

At the Nogli a beautiful milky-white quartzite that takes a high polish, and is sometimes mistaken for marble, appears dipping south-west. This rock, which, I think, represents the Krol quartzite, is followed by trap.

The trap is a hornblendic variety; some of it is distinctly amygdaloidal;[1] and it is intercalated with slaty beds having a micaceous glaze, and resembling the trap in colour. Somewhere near the middle of the series three bands of white quartzite occur intercalated between beds of slaty rocks.

The volcanic rocks here displayed appear to me to occupy very much the same horizon as the altered basalts of the Dalhousie region, which occur between the silurian and the carbo-triassic series. Their relation to the white quartzite band at the Nogli, and to the quartzites interbedded with them, which presumably represent the Krol quartzite, would however seem to indicate that they are somewhat younger than the Dalhousie volcanic series. In this respect the Rampur lavas agree with those of Kashmir, where Mr. Lydekker observed that, in some instances, they pass up into his Kuling series,[2] the equivalents of the infra-Krol series of the Simla region,[3] and of the lower carboniferous series of Europe and Australia.[4]

I am disposed to regard the quartzites intercalated with the lavas, as well as the quartzite at the Nogli, as the equivalents of the Krol quartzite. Mr. Medlicott has pointed out[5] that these beds sometimes attain considerable thickness, as at Boileauganj. At Simla the deposition of the sand, of which these quartzites were originally composed, was unbroken, but in the Rampur area it was, apparently, interrupted by lava-flows and by the deposition of mud, into the composition of which volcanic ejectamenta probably largely entered, but the deposit of sand was resumed from time to time when the volcanic energy was dormant.

The trap series lasts with a south-easterly dip as far as Rampur; here there is a fault along the axis of a synclinal flexure which brings down the milky white Krol quartzite and the trap series, both of which on the north side of the fault have a north-easterly dip. The trap series to the north of Rampur is evidently the same as that which occurs to the south of the town, and the white quartzite which I have described as occurring about the middle of the series, between the Nogli and Rampur, re-appears in a similar position in the series to the north of the town. Owing to vegetation, however, I could not see whether slaty beds are intercalated with the latter or not.

[1] I did not notice any of the amygdaloidal variety *in situ*, but blocks of it are very numerous on the roadside, and are without doubt of local origin.

[2] Memoirs, Geological Survey, Vol. XXII, pp. 133, 135, 138, 141, 148, 217, 222.

[3] *Ib.* p. 201.

[4] *Ib.* p. 161.

[5] Mem., Geol. Sur., Vol. III, pp. 24, 34.

The traps on the north side of Rampur have much the same general appearance as those to the south, with the exception that they are more metamorphosed and consequently appear more distinctly hornblendic to the unaided eye. In the northern outcrop many of the beds are distinctly slaty in texture, and there is a comparative absence of the amygdaloidal variety. I once found an amygdaloidal block by the roadside, 2 or 3 miles north of Rampur; and as the block could not have travelled up the river, and as the non-amygdaloidal portion of it exactly resembled the local rock, the probability of its having been derived from a local source is very great. The amygdules formed a band along the top of this block. This is the only occasion on which I found amygdaloidal trap north of the town of Rampur.

Whatever differences are observable between the beds to the north and to the south of Rampur, I attribute partly to the probability of volcanic ash having taken a larger part in the formation of the beds to the north than in those to the south of the town, and partly to the northern beds being more within the region of metamorphism.

The actual line of the fault which I have described as occurring at Rampur may be seen, in section, on the right bank of the Satlej, a little to the north of the town; and the white quartzite with a north-easterly dip is there let down against the dark trap series; and the line of division between the two is as sharp as if it had been cut with a knife.

In my paper, published in 1877, I stated, with reference to the first appearance of the trap at the Nogri, that the "strong quartz beds are burst asunder and twisted about by the trap in a wonderful manner." I was young, as an observer, then; and in those days the Sutlej trap was believed to be an intrusive rock. The trap where it first crops out certainly has the appearance above described, but this, I think, is deceptive, and is produced by contortion, which has been very severe at this point, and by small local faulting. The idea of intrusion is also favoured by the fact that the trap is jointed at right angles to the bedding of the quartzites.

In the middle quartzite band intercalated with the traps to the south of Rampur, an instructive example of columnar structure is to be seen: a bed of white quartzite has weathered into a perfectly rounded column, 2 feet in diameter and about 15 feet long. Its frayed end shows a tendency to split up into a series of annular coats like an onion. This struck me as interesting in connection with the bacillary structure of the Boileauganj quartzites[1] at Simla. The columnar structure above described is probably due to the heat produced by beds of lava flowing over beds composed of silicious materials; and if so, the bacillary structure of the Boileauganj quartzites may be referred to a similar cause.

The metamorphism of the Jako (Simla) beds has been conjecturally referred by Mr. Medlicott[2] to the heat produced by igneous masses injected as sheets, or flowing over the Jako beds from the direction of Hattu. The rapid decline of

[1] Mem. Geol. Sur., III, p. 35.
[2] Punjab Gazetteer: Geology.

metamorphism on descending from the Krol schists, on the top of Jako, to the silurian beds in the valleys below, almost completely shuts out the supposition that the metamorphism of the Jako rocks can be due to tangential pressure or to agencies operating from below, for in the Simla region contortion is rampant in the strata of the valleys and inconsiderable on the hill-tops; whilst the stratigraphy of Jako, and its neighbourhood, is such as to altogether exclude the supposition of inversion.

The Kot peak, a few miles to the north of Hattu, where the gneissose granite is perfectly granitic, probably represents a centre of volcanic activity, and is probably the long-buried root of a volcano from whence sheets were injected into the neighbouring strata, and from which streams of acid lava, long since removed by erosion, were poured out far overhead.

The traps to the north of Rampur are followed by a very thick series of white and grey quartzites having the normal north-easterly dip. These are, I think, the equivalents of the silicious beds between Narkanda and Kotgarh.

At the village of Pishwára[1] a broad band of hornblende rock crops out. No evidence of its intrusive character is visible from the road. The jointing of the rock is at right angles to the bedding of the quartzites. A specimen of this rock is described in part II, of this paper, No. 20.

As Gaora is neared, the quartzites become micaceous, and a little south of Gaora pass into white hydrous mica schists that decay into a thick white powder. These beds reminded me strongly of some schists in the Dalhousie area that crumble into a white soapy powder, as, for instance, those seen under Tikri. In the Dalhousie area, I have classed these rocks among the lower silurians, and I think the beds in the Sutlej valley occupy a similar position. In the section from the Thera mall to Banikhet I think the Sutlej valley schists are represented by the paragonite (?) slate No. 47 of my microscopic sections.[2]

Proceeding onwards to Gaora, the mica schists, just described, dip under foliated rocks, and these pass into gneissic beds. The latter are, I think, the oldest rocks met with in the section under description, and are of lower silurian, or cambrian, age.

At Gaora the dip is north-north-east, but it rounds towards the west, and at Sarhan it is west-north-west; the road to Sarhan works back across the strike of the rocks, and at the Manglád stream the white hydrous mica schists are again reached. Some beautiful specimens of these rocks, which might be mistaken for talc schists, may be obtained here.

On the ascent from the Manglád Nála to Sarhan, the traveller passes back again across the strike to the gneissic beds seen at Gaora.

In the cliffs on the roadside, some 2 or 3 miles short of Sarhan, a hornblende rock crops out which is described under No. 23 of Part II. At this point it is almost certainly intrusive in the mica schists; if it is not intrusive, its onward course must be abruptly cut off by a fault of which no other trace is visible.

This rock is of distinctly foliated structure. It frequently recurs on the road

[1] Apparently the village named Pasada on the Atlas sheet.

[2] Records, Vol. XVI, p. 140.

up the Sutlej valley to Wangtu, sometimes in the schists and sometimes in the gneissose granite. It is not necessary that I should note every appearance of it.

Beyond Sarhan the dip is N. 11° E. The road lies in the gneissic beds, and in the schists, but the white hydrous mica schists are not again reached.

Between the 93rd and 94th milestones, a dyke of this peculiar rock appears in the cliffs, along the face of which the road has been carried by blasting. A dyke traverses the rocks just at the spot where the late Sir A. Lawrence was killed, and the white stone cross erected to his memory is fixed on the dark diorite and marks the place of the accident. In those days the road was carried along the face of the cliff by a balcony; this gave way as Sir A. Lawrence was riding along it, and he was precipitated down the precipice and killed on the spot.

The foliated quartz-diorite here appears to be intrusive: it certainly cuts across the foliation of the gneissic beds in one place.

About three quarters of a mile beyond this point bands of fine-grained granite begin to occur in the gneissic beds, which dip north-north-west, and doubtless the granite is intrusive in the gneiss. There are three or four such bands, and then the gneissose granite itself appears. At first the latter is here and there gneissose, but afterwards it becomes granitic and finely porphyritic.

The gneissose granite lasts until the Kandla nála[1] is reached, when mica schists come in for awhile, the gneissose granite reappearing a little to the south of Chora. It seems to me not improbable that these outcrops of gneissose granite are continuous; if they are, the granite cuts directly across the strike of the schists. The point can only be determined by exploring the side of the mountain above Kamparang and Chora, which I had not time to do.

The gneissose granite continues from Chora to about the 102nd mile from Simla, *viz.*, to about 2 miles on the Sarhan side of Tharanda, where gneissic rocks with granite veins in them come in. The dip here is nearly perpendicular, inclining a little to the north of west. Between the 101st and 102nd milestones, gneiss appears to alternate with granite, and the impression left on my mind by a roadside examination of these beds, is that at the junction of the main mass of the gneissose granite and the sedimentary beds, the latter are abundantly penetrated by sheets and veins of the granite. The gneissic portions between the granite sheets are much riddled by granite veins.

Near the 102nd milestone there has been much crushing, and the gneissose and schistose beds vary in dip from west to south, and from flat to perpendicular, within a few yards.

On the descent to the nála under Tharanda[2] I observed the hornblende rock (quartz-diorite) twice; and on the ascent to Tharanda it crops out five times. These outcrops are probably continuous and form one broad dyke; but owing to the excess of vegetation I was not able to see whether this is so or not. A sample of this rock is described in Part II, No. 26.

[1] The Kandla nála is, I think, the stream flowing down from the Bhosleh Trigonometrical Station into the Sutlej, to the west of the village of Shilwan. Chora, which is not marked on the Trigonometrical Survey Atlas, is about one and a half miles to the north of this stream.

[2] This stream is I think, the one flowing down from the Bhosleh Station into the Sutlej to the west of the village of Thusaring. Tharanda is, I think, about half a mile or so to the east of the Nanaspar Station marked on the map.

After leaving Tharanda one rounds the spur before commencing to descend in an easterly direction to the stream under Pawanda.[1] The gneissose granite crops out again here, and it is probably continuous with the outcrop south of Tharanda.

The gneissose granite is at first fine-grained and non-porphyritic; but afterwards all the varieties of this rock, namely, the gneissic, the porphyritic, and the perfectly granitic, are seen. Veins of the fine-grained non-porphyritic variety occur both in the gneissose and in the porphyritic varieties.

On the descent to the nála under Pawanda, near where the 106th milestone from Simla used to stand,[2] an outcrop of the hornblende rock (quartz-diorite) occurs, having a width of about a quarter of a mile. It runs up the mountain side in a perpendicular direction. In this diorite there are seven or eight perpendicular dykes of the porphyritic granite and one perpendicular dyke of the fine-grained non-porphyritic granite. Mica has been developed in the foliated diorite apparently by contact action. A specimen taken from the diorite at its contact with the granite is described in Part II, No. 25. One dyke of the hornblende rock (diorite) has all the appearance of having passed straight up the middle of one of the perpendicular dykes of porphyritic gneissose granite. If this is not really the case, two narrow dykes of the granite must have run a perfectly parallel course, very close together on either side of a thin dyke of the foliated diorite. The latter has a sharp clean-cut edge, and looks superficially like one of those perpendicular dykes of basalt one so often sees traversing beds of lava in the crater walls of a volcano. A hand specimen taken from this narrow dyke of hornblende rock (diorite) is described under No. 27, Part II.

If the wide outcrop of the hornblende rock which occurs at the 106th mile from Simla is continuous with that on the south side of Tharanda, about the 103rd mile from Simla (and the one outcrop strikes in the direction of the other), it is clear that the hornblende rock must strike obliquely across the gneissose granite; for the outcrop on the ascent to Tharanda occurs on the western margin of the granite, and indeed clear of it, whereas the outcrop opposite Pawanda occurs either at, or near, the eastern margin of the granite. Appearances in the field therefore favour the supposition that the hornblende rock is an eruptive rock intrusive in the gneissose granite and that it is of the same age as the latter, for it is itself penetrated by dykes of the granite.

On the ascent from the stream to Pawanda one crosses over the strike of the rocks, and those seen on the descent to the stream are recrossed; owing to vegetation, however, there are not the same facilities for observing their details.

From Pawanda to Narchar,[3] owing to forests, the rocks are not often seen *in situ*, but when seen they are fine-grained non-porphyritic gneissose granites.

[1] Derived, I should imagine, from *pawan* "wind," a speaking commentary on what the climate must be in winter. The stream alluded to is the one shown on the map as flowing down from the "Snowy Peak No. 5," into the Sutlej to the west of Paug. Powanda is on its right bank.

[2] The majority of the milestones, *viz.*, painted boards let into stone columns have been carried off by Buddhist travellers from Tibet, under the impression that the words so many "miles from Simla" are an English invocation of the Deity.

[3] Narchar, one of the residences of the Sutlej valley Forest Officer, is not marked on the map. It is 4 miles on the Simla side of Wangtu.

Near Narchar veins of white oligoclase intrusive granite begin to appear, and as Wangtu is neared, these veins become more abundant.

At Wangtu all varieties of the gneissose granite are well seen: some are perfectly granitic; some are of the ordinary porphyritic type; some reminded me of the unporphyritic varieties of the Dalhousie area, as seen on Dainkund, in the Chuari pass, and at Sihunta. Veins of the latter variety, which is not to be confounded with the white oligoclase granite, are to be seen in the porphyritic kind, whilst the white oligoclase granite traverses all the other varieties.

At page 219 of my first paper (*supra*, Vol. X) I described a foliated hornblende rock, which I considered to be an igneous rock in an advanced stage of metamorphism, traversing the gneissose granite (then termed granitoid gneiss) and behaving as an eruptive rock. A good place for observing it is at the mouth of the Wangar stream, where it joins the Sutlej at Wangtu. I made a sketch of this on the occasion of my first visit, and another when I was last there. An attempt to give the reader the benefit of this is made at fig. I of the plate attached to this paper. A good picture from an artistic point of view cannot be made of the subject, as it has to be viewed from above, and it is a physical impossibility to get down to a level with it on the opposite side of the Wanga stream. The rock itself can be reached, and on both occasions I brought away hand specimens of the foliated diorite, but the side of the rock to which access is possible is not a good one for a sketch.

Previous to commenting on the stratigraphy of the section now described I think it desirable to give the results of an examination of thin slices of the Rampur traps and of the hornblende rocks of the Sutlej valley as seen under the microscope. The rock seen at the junction of the Wangar and Sutlej rivers is described under No. 29.

PART II.

NOTES ON THE MICROSCOPICAL EXAMINATION OF THE TRAPS, DIORITES AND HORNBLENDE ROCKS OF THE SUTLEJ VALLEY.

Traps on the south side of the town of Rampur.

No. 1.—A greenish grey amygdaloidal trap. Sp. G. 2·87.

No. 2.—A fine-grained trap. Sp. G. 2·88.

No. 3.—Taken from a bed that crops out close to the town. Sp. G. 2·89.

No. 4.—Taken from the middle of the southern outcrop. Sp. G. 2·87.

No. 5.—Taken from near the southern margin of a bed that crops out on the bank of the Sutlej river. Sp. G. 2·91.

These specimens are of dark-grey colour, No. 5 having a somewhat greenish tinge. No. 3 is a speckled rock, and, with the aid of a pocket lens, it is seen to be distinctly crystalline. The other specimens may be described as being of compact texture, though minute blades of hornblende may be discerned in them with a pocket lens.

M.—No. 1 consists of a mixture of hornblende, mica, and felspar; the two former being abundant. Magnetite and epidote are also present. Most of the

felspar is tolerably fresh and much of it is distinctly triclinic: it contains microliths apparently of hornblende.

The hornblende is in long slender prisms, or fibres; but cross-sections exhibit the characteristic prismatic cleavages.

The amygdules contain zeolites, epidote, mica, iron pyrites and calcite. The presence of long strings of perfectly formed mica in the amygdules renders it probable that the mica seen in the trap itself is also of secondary origin. In transmitted light it varies from a brown-green to an olive-green colour.

The amygdules above described contain a few minute liquid cavities with bubbles, but none were detected elsewhere.

Nos. 2 to 5 contain hornblende, felspar, and mica in minute leaves. The hornblende is generally dark-green in colour, and is powerfully dichroic, except in No. 4 in which the hornblende is very pale in transmitted light, in the latter, however, the dichroism is still distinct. Nos. 2 and 3 contain calcite, and 2, 4, and 5, a few grains of free quartz. The quartz of 4 and 5 contain some minute liquid cavities with bubbles, but high powers are required to detect them. Gas pores are sparsely present in all the above specimens (2—5). Nos. 2 and 5 contain some hæmatite, and a little epidote. Sphene is abundant in No. 4, and one of the slices of No. 4 also contains a garnet.

The felspar in Nos. 2 to 5 is visibly triclinic in the majority of crystals. No. 5 appears to contain a few prisms of orthoclase, but this species of felspar could not be identified in any of the other slices. A piece of microcline is present in No. 4.

In all the above slices (2—5) more or less of a residuum or base can be made out, which seems to consist in part of quartz., in part of felspar, and in part of a crypto-crystalline admixture of both.

With the exception of a few specks in No. 4 the magnetite in all the other thin slices appears to have been converted into ferrite. Microliths of hornblende are abundant in all the specimens examined under the microscope.

Trap on the north side of the town of Rampur.

No. 6.—Amygdaloidal trap. Sp. G. 3·06. One half of the hand specimen is compact; the other half is crowded with small amygdules. Some of them are round, but others are somewhat elongated, the longest axes being, more or less, in the same general direction.

M.—The ground mass is composed of a granular crystalline material which is greenish white in reflected light. In transmitted light it is translucent rather than transparent, and is of a dull whitish or yellowish green. It is not dichroic and between crossed nicols it polarises in a dull patchy way. It is probably a transitional form between hornblende and epidote. In this ground-mass powerfully dichroic crystals of hornblende are embedded. Epidote is also abundant. A little free quartz is present here and there, but I have not observed any felspar.

The amygdules are composed of quartz, epidote, and calcite.

A little magnetite is sprinkled about in the slice. The free quartz in the

ground-mass contains a few liquid cavities with moveable bubbles, but there are the amygdules.

No. 7.—Sp. G. 2·93.
No. 8.—Sp. G. 2·94.
No. 9.—Sp. G. 2·93.
No. 10.—Sp. G. 3·00.
No. 11.—Sp. G. 2·89.
No. 12.—Sp. G. 3·03.
No. 13.—Sp. G. 2·93.

All these specimens (7—13) are of dark-grey colour, with a slight inclination to a dull green tint. Nos. 8 and 9 are somewhat fissile, and have a feeble micaceous glaze on the splitting surface. All are compact, but with the aid of a lens micro-prisms of hornblende can be made out in most of them, and No. 12 seems to be almost made up of prisms of this mineral. With a lens the quartz and felspar can be distinguished from the hornblende in Nos. 9, 10, and 11; whilst No. 11 is seen to have a fine foliated structure.

The specimens 7 to 13 may be divided into two classes; namely, those in which the ground mass consists wholly, or principally of quartz (9, 11 and 12); and those in which it consists nearly wholly of felspar, as in Nos. 8 and 13 in which there is no quartz. No. 7 occupies an intermediate position between the two classes.

Epidote is present in Nos. 8, 9, 10 and 11: it is usually quite colourless in transmitted light. Magnetite is present in all slices except those of Nos. 7 and 8, in which ferrite takes its place.

The felspar in Nos. 7, 8, 10, and 13, is, for the most part, visibly triclinic and none of it can be recognised as orthoclase.

The quartz, in these slices, is in micro-grains, and in No. 12 the latter exhibit a tendency to assume crystallographic outlines.

The dichroism of the hornblende is very brilliant and axial sections exhibit the cross cleavage well. In No. 12 the prisms present in some cases very regular outlines. In all these slices microliths of hornblende are abundant in the ground-mass.

I have not observed any liquid cavities with bubbles in these slices, except in some of the epidote of No. 11, in which they are rather numerous.

Narkanda quartz-diorite.

Nos. 14 and 15.—Sp. G. 2·95. From an outcrop on the road, about 3 miles on the Mattiana side of Narkanda, noted by Mr. Medlicott in his Memoir "*On the Geological structure and relations of the southern portion of the Himalayan range between the Rivers Ganges and Ravee.*" Memoirs, Geological Survey, Vol. III, p. 40.

M.—This rock is composed of hornblende, mica, triclinic felspar, and a little quartz. Magnetite, ferrite, and a little calcite are also present. Judging from the absence of dichroism, and from the angle of extinction, one of the slices appears to contain some augite which seems to have escaped conversion into hornblende.

I have not observed any liquid cavities with moving bubbles, but some portions of the hornblende are full of gas cavities and inclusions that follow two directions of cleavage. Liquid cavities with bubbles, full of air or gas, are also present in the hornblende. Many of the microliths present in the slice are cracked and contain fixed bubbles. The appearance of the slice is that of an intrusive rather than that of a contemporaneous igneous rock, and seems to be a normal quartz-diorite.

Between Rampur and Gaora.

No. 16.—Sp. G. 2·96. A very fine-grained speckled hornblende rock, in white quartzite, on the ascent from Rampur to Gaora. The hand specimen exhibits an incipient foliation. At first sight, from the mode of outcrop the rock appears to be intrusive in the quartzite, but on a careful examination of the outcrop on the occasion of my last visit, I failed to obtain any actual evidence of intrusion.

M.—The ground-mass consists of granular quartz. Hornblende is abundant. The slice also contains a little epidote, colourless in transmitted light, and some micro-garnets. No liquid cavities could be discovered. The slice contains no felspar, and magnitite is replaced by ferrite.

No. 17.—Sp. G. 2·95. A beautifully crystalline diorite.

No. 18.—Sp. G. 2·96. A closely similar rock. It differs from No. 17 only in the felspathic element not being quite so prominent.

Both specimens are highly crystalline rocks; the minute prisms of hornblende set in a white matrix being visible ta the unaided eye. The hornblende radiates in all directions, and there is not the slightest approximation to parallelism in the arrangement of the constituent minerals. These specimens appear to belong to the same type of rock as No. 4; there seems be an advance in crystallization—that is all.

M.—The hornblende is in massive prisms, most of which are twinned. When seen in section they are six-sided, and exhibit the prismatic cleavages well. The hornblende is also present in the form of micro-prisms and crystals.

The other constituents of the rock are felspar, quartz, magnetite, and mica. Some of the felspar is visibly triclinic: the mica is not abundant, and the quartz is subordinate to the felspar.

The rock contains air or gas inclusions, and some liquid cavities with fixed bubbles. Microliths with fixed bubbles and elongated shrinkage cavities are also present. The bubbles in the liquid cavities are large compared with the size of the cavities enclosing them. There are some colourless microliths that may be apatite.

The aspect of the rock under the microscope is that of an eruptive one.

It is apparently the same rock as No. 4, but of more granitic structure, being almost completely holocrystalline. The sphene of No. 4 is not present in very thin slices of Nos. 17 or 18, but appears in the specimen next to be described.

No. 19.—Sp. G. 3·04. A dense, fine-grained hornblende rock, speckled with minute white specks.

M.—This specimen so closely resembles No. 17 in microscopic structure that a

separate description is unnecessary. It contains what appears to be sphene. It is more translucent than titanite usually is, and it is granular in structure, presenting none of the characteristic forms of sphene; on the other hand its optical characters agree precisely with those of sphene; its dichroism and powerful double refraction being very characteristic. Every piece of sphene in the slice (and they are numerous) contains very many irregularly shaped fragments of ilmenite, or magnetite, probably the former.

No. 20.—Sp. G. 2·99. This specimen is made up of hornblende, mica, and quartz. Ilmenite, or magnetite, is also present, apparently the former. It is associated with sphene as in No. 19. The hornblende is much corroded and eaten into by granular matter and minute grains of quartz. Microliths, some of which are of mica, contain fixed bubbles, and many of them enclose a plurality of them. The slice does not contain any liquid cavities with moving bubbles.

Between Gaora and Sarhan.

No. 21.—Hornblende rock. Sp. G. 3·03. The hornblende is of the same character as that of the specimens already described. The ground-mass is composed of a mixture of quartz and triclinic felspar. The slice contains numerous small, well-crystallized garnets, some schorl, magnetite, hæmatite, and a little mica. I have not detected any liquid cavities with moving bubbles, but some of the microliths contain internal cavities. The hornblende encloses numerous micro-inclusions which contain fixed bubbles. A quartz grain sliced at right angles to the optic axis, contains an oval-shaped inclusion of glass with a large oval-shaped fixed cavity at one side of it. The inclusion appears to be of glass, for it is almost invisible in reflected light, whilst when tested with, and without, the quartz plate, in transmitted polarised light, it is quite inert.

No. 22.—Sp. G. 2·90. From a bed in mica schist close to the locality from which No. 21 was taken.

This is a distinctly foliated, fine-grained, hornblende schist. The weathered surface is micaceous.

M.—There is a perfect parallelism in the arrangement of the hornblende, with lines of finely granular quartz between the strings of hornblende prisms. The latter are not in continuous straight lines, but merge with each other here and there like the meshes of a net. Felspar is very sparse. The hornblende is in acicular prisms, and is rarely massive. I have observed no liquid cavities with bubbles. This is a very metamorphic-looking rock.

No. 23.—Sp. G. 3·04. A very fine-grained rock, apparently intrusive in the schists, on the road side 2 or 3 miles south of Sarhan.

M.—Under the microscope a parallelism is observable in the arrangement of the minerals. The slice is composed of hornblende in bladed prisms, and quartz, the grains of which show sharp crystallographic outlines. A considerable amount of magnetite, in strings in the hornblende, and some ferrite, are present. There are no liquid cavities with moving bubbles, and the rock presents no special features. I only detected one piece of felspar in the slice, and this gave no indication of twinning.

Between Sarhan and Taranda.

No. 24.—Hornblende rock. In this specimen the hornblende predominates largely over the quartz. There is a present tendency to hexagonal outlines in the grains of the latter mineral. A little triclinic felspar is present. The slice contains microscopic garnets, but they are not numerous. Liquid cavities with movable bubbles are present in the quartz, but they are sparse. A few microliths contain vacuoles or shrinkage cavities. Some magnetite is also present.

No. 25.—Hornblende rock opposite Pawanda in contact with a dyke of gneissose granite. The specimen was taken from the contact edge.

M.—Half the hand specimen has been converted into mica; the mica appearing along the line of contact between the hornblende rock and the gneissose granite. Under the microscope the hornblende, along a line parallel to the mica, has quite lost its colour; patches of green colouring matter, however, being left here and there in the colourless prisms. All the hornblende at the outer side of the slice is deeply coloured, varying from a yellow to a blue green. The coloured portions are powerfully dichroic, and the cross cleavage is typically exhibited in both the coloured and colourless hornblende.

There is a decided parallelism in the arrangement of the materials. The hornblende prisms are set in felspar and quartz, the former probably predominating. Much of the felspar is visibly triclinic. The slice contains magnetite and some garnets.

There are numerous microliths which contain cavities and inclusions. There are a few liquid cavities with fixed bubbles.

No. 26.—Hornblende rock. The hand specimen was taken from the outcrop on the ascent to Taranda, from the stream at the 102nd mile from Simla, Sp. G. 2·94. In one place the outcrop is distinctly fluted.

M.—The hornblende is very perfect; dichroism is intense, and the prismatic cleavage is well-marked. The felspar, much of which is visibly triclinic, preponderates, I think, over the quartz; but in this, and the other Sutlej valley specimens, it is extremely difficult to discriminate between the quartz and felspar when the twin lamellæ of the latter are not visible; the felspar is very glassy, and in external outline, and in its appearance under the polariscope, it does not sensibly differ from the quartz. The minute size of the grains adds much to the difficulty. A close examination, however, with sufficiently high powers, will often bring cleavage lines to light, which enables one to discriminate between the two minerals.

Liquid cavities with bubbles are present, and gas inclusions, some of which appear to have deposited mineral matter on cooling, are somewhat abundant. Microliths containing vacuoles are numerous; one, apparently of hornblende, contains four rounded vacuum bubbles of different sizes, whilst in some others they are specially abundant. There are some micro-garnets.

No. 27.—Sp. G. 2·98. A very fine-grained, almost compact, hornblende rock, from a dyke in front of Pawanda, on the road-side, 106 miles from Simla, that has apparently intruded through the centre of a dyke of the gneissose granite.

M.—The slice examined is composed of hornblende and quartz, principally the

former. The quartz is in minute, well-crystallized grains, and there is no parallelism in the arrangement of the constituent minerals. A little triclinic felspar is mixed up with the quartz, and the slice also contains a little mica, magnetite and ferrite.

Some liquid lacunæ, with fixed bubbles, large in proportion to the cavities, are to be observed in the quartz. Gas bubbles and irregularly shaped gas inclusions are common in both the quartz and hornblende. The latter also contains numerous other inclusions, most of which appear to be filled with "stony" material, and contain round and fixed bubbles—often a plurality of them. These bubbles do not hold either air or gas, and seem to be shrinkage cavities. One cavity contained a large gas bubble combined with liquid or "stony" matter. Other stone cavities have internal deposits of a dark mineral, which, in general, has formed along their inner borders.

No 28.—A quartzose mica diorite.—The hand specimen was taken from the banks of the Sutlej Nachar, near the hot springs. Sp. G. 2·84.

There are numerous veins of intrusive granite in this locality; one of them on the right bank has cut through the hornblende rock and converted it into a mica trap. This specimen is a crystalline granular mixture of biotite, hornblende, felspar, and quartz. No parallelism of structure is visible.

M.—Hornblende is extremely subordinate to biotite and quartz to felspar: the latter is very hyaline, and most of it is visibly triclinic. The biotite and hornblende together about equal the felspar. Micro-sphenes are very numerous, and the slice contains a little magnetite.

Liquid cavities with moveable and fixed bubbles are abundant; the bubbles are large, and cover about half the area of the cavities.

Microliths are extremely numerous; some are cracked, and many of them contain round and elongated vacuoles. Some contain a plurality of them. The slice contains liquid cavities with gas bubbles, the bubbles occupying above three fourths of each cavity. The whole aspect of the rock is that of one of the igneous class.

No. 29.—Hornblende rock, Wangtu. Sp. G. 3·02. The rock at Wangtu is very fine-grained, and shows distinct parallelism of structure when examined with a lens.

The hornblende is very green in transmitted light, and is powerfully dichroic. The mineral next in abundance is quartz. There is a little triclinic felspar present and multitudes of micro-sphenes.

The quartz is moulded on to the hornblende; liquid cavities with moveable bubbles are present, but they are not numerous. Gas cavities are also present.

The Wangtu specimens contain microliths with shrinkage cracks and vacuoles.

No. 30.—Hornblende rock. Between Wangtu and Chigaon. Sp. G. 3·02. This appears to be the same bed as that seen at Wangtu, but it has here become a fine-grained mixture of biotite, hornblende, quartz, and felspar; the biotite and hornblende being about equal in amount.

The hornblende is so black and lustrous, and the grain is so small, that it would require a very sharp eye and a good pocket lens to detect the change in the rock. It still exhibits a fine but decided foliation. A few micro-garnets appear to be present.

Under the microscope the rock is seen to be perfectly crystalline. *Microliths* abound, many of them being of hornblende; and a large number of them contain shrinkage cracks and vacuoles. Liquid cavities with moveable bubbles are present, but sparse.

No. 31.—Hornblende rock. This specimen was taken from the same locality as No. 30, close to a small granite dyke that cuts across the bed. As compared with the last specimen, quartz has dwindled into comparative insignificance; and felspar, nearly all of which is visibly triclinic, predominates largely over it.

The slice contains liquid cavities with moving bubbles, and inclusions with mineral deposits and fixed bubbles. Magnetite or ilmenite is present in some abundance.

PART III.

REMARKS ON THE CHARACTER OF THE ROCKS DESCRIBED IN THE PRECEDING PARTS, AND ON THE STRATIGRAPHY OF THE REGION.

Amongst the trap south of the town of Rampur, amygdaloidal specimens are not uncommon; the hornblendic trap is intercalated with slaty beds, and about the middle of the series three bands of quartzites occur separated by beds of slate.

The amygdaloidal character of some of these traps seems to point decidedly to a volcanic origin, and I see no reason to class them with the plutonic rocks. They crop out very nearly on the horizon occupied by the basic volcanic series of the Dalhousie area, and their position agrees well with that of the Kashmir traps, which occasionally pass up into the lower carboniferous series.

The Rampur traps differ from those south and north-west of Dalhousie, inasmuch as the amphibole element takes a decided place in them; but I have pointed out in my last paper that the Hulh and Sao traps, to the north-east of Dalhousie, show a decided tendency to become hornblendic.

It may be that the volcanic rocks, in their extension into the Rampur area, underwent a change of type. I have, in my last paper, given my reasons for believing that the view adopted by Mr. Lydekker in his Memoir on Kashmir is correct, and that the ancient lavas of the North-Western Himalayas were not fissure eruptions, but were emitted by volcanoes dotted over the then surface of the country. That being the case, there would be nothing surprising in the fact that volcanic activity extended over a considerable period in time, or that the lavas which issued from the different volcanic centres differed from each other considerably in type. That the latter was really the case will, I think, be clearly seen if we compare the results of the microscopic study of the traps south of Dalhousie[1] with those north of Bhandal, and with those at Hulh and Sao.[2]

I am disposed, however, to attribute the hornblendic character of the Rampur traps to another cause, namely, to metamorphic action.

[1] Rec. Geol. Surv., Vol. XVI, p. 178.

[2] See in my last paper.

The amygdaloidal character of some of the Rampur traps south of the town indicates that these traps are true lavas; whilst it is clear to me that the rocks at Rampur, immediately north of the town, belong to the same series as the traps on the south of the town. The high specific gravity of the hand specimens from both the north and the south of the town, on the other hand, seem to indicate that their affinities are with the basic lavas rather than with the hornblende-andesites.

Augite, as is well known to mineralogists now-a-days, is not a stable mineral; but on the contrary it exhibits a strong tendency to set up molecular changes, in the presence of metamorphic action, that result in its settling down into the more stable form of hornblende.

An interesting *résumé* of the evidence bearing on this point has recently been published in the American *Journal of Science*,[1] and it will be sufficient to refer to that article, and to the authorities quoted therein, as a guide to any one who wishes to pursue the investigation. The papers of Mr. J. A. Phillips (Q. J. G. S., XXXII, p. 155, and XXXIV, p. 471) in which the change of augite into hornblende is proved, and certain "greenstones" are shown to be altered doleritic lavas, may also be referred to.

"Jukes long ago," Mr. Williams writes,[2] "suggested that many areas of hornblende rocks might be accounted for by the alteration of old lavas, and this seems now to be fast gaining ground." Hornblende schists, in particular, have, it has at different times been suggested, resulted from the alteration of basaltic tuff.[3]

"Quite recently," to quote again from Mr. Williams' paper, "the possible widespread geological importance of the paramorphosis of pyroxene to amphibole in accounting for the existence of many areas of hornblendic rocks by the alteration of other rocks, originally augite, has attracted much attention. This change has been carefully followed in Norway, Austria, Saxony, and several other European localities, as well as on this continent in New Hampshire, Wisconsin, and in the region about Baltimore."

One remark made by Mr. Williams has an especially important bearing on the inquiry into the origin of the Sutlej valley hornblende schists, namely, "In the great gabbro area, west of Baltimore, the massive diallage and hypersthene rocks occur everywhere imbedded in, and passing by gradual transitions into more or less schistose amphibolites, which differ from them mineralogically only in the crystalline form of the bisilicate constituent. These amphibolites have, throughout the whole area, a nearly parallel strike and dip, and many other facts, which cannot here be enumerated, indicate that their schistose structure is like slaty cleavage, the result of lateral pressure. That the amphibolites have resulted from the paramorphosis of the pyroxene in the gabbros is abundantly proven both by microscopic study and their relations in the field, and the fact is very significant that throughout the area, as a rule [the italics are in the original paper], *the*

[1] On the Paramorphosis of Pyroxene to Hornblende in rocks; by Geo. H. Williams, Vol. XXVIII, p. 259 (Oct. 1884).

[2] See also Geikie's Text-Book of Geology, p. 121.

[3] For instance see Quar. Jour. Geol. Sur., Vol. XXXIX, p. 19.

schistose structure is developed in proportion to the completeness of the paramorphosis."

I note in passing that one of my hand specimens from the north side of the town of Rampur exhibits a distinct parallelism of structure, whilst some beds might be callen hornblende slates as their fissile character is well marked. The latter, I think, are probably altered ash beds.

The view that the hornblendic character of the Rampur traps is due to metamorphism, is favoured, not only by the general considerations indicated above, but by the fact that whilst observations in the field showed the rock series to the north of the town to be a mere repetition of that seen on the south of the town, the metamorphism of the northern wing of the syncline—that nearest to the main axis of granitic eruption and metamorphic action—is more advanced than that of the southern wing; the beds of which the former are composed looking more like hornblende rocks, and less like lavas, than those which compose the southern wing.

Another consideration is, if the rocks are not altered lavas, what are they? The amygdaloids of the southern wing seem to shut out the supposition of their being either metamorphosed sedimentary beds or plutonic eruptive rocks. The Rampur rocks occur, it seems to me, on the horizon of the volcanic series of Kashmir and Dalhousie, and I think they must belong to that series.

The view was adopted in the *Manual of the Geology of India*[1] that the traps of the Biás and Sutlej valleys were intrusive and connected with the "extreme crushing and disturbance the slates and limestone have undergone in those positions." My microscopic study of the Biás valley traps exposed at Darang and Mandi,[2] has shown that the rocks at both those places are altered basalts resembling those south of Dalhousie. The traps at Suni in the bed of Sutlej are very much altered by aqueous agencies—a fact probably connected with the presence of hot springs in that locality; but the appearance of these traps, in the field and under the microscope, leads me to class them with the lavas of the Dalhousie and Kashmir areas. My reasons for claiming the traps of Rampur as altered lavas have been given in the preceding pages.

In the Dalhousie area the lavas come in above the upper silurian conglomerate and below the carbo-triassic series, as is well seen in the neighbourhood of Bhandal, Hulh, Sao, and Aulansa, the details of which outcrops were given in my last paper. The traps under discussion appear to occupy a similar position in the valleys of the Biás and Sutlej, with the exception, as we have seen, that at Rampur they extend into the lower carboniferous series. They do not occur either in the Simla or in the Dalhousie area in the great series of carbo-triassic limestones, but they often touch, and are never far from those limestones in the Dalhousie area, and they appear to occupy a similar position at Darang and Mandi; at the Gairu mountain[3] on the north of the Sutlej; and at Suni;[4] whilst they succeed the infra-Krol slates and the Krol quartzite at Rampur.

[1] Manual, Geol. Sur., p. 606.
[2] Records, Geol. Sur., Vol. XV, p. 155.
[3] Memoirs, Geol. Sur., Vol. III, p. 50.
[4] Memoirs, Vol. III, p. 48.

The contortions and disturbance which the rocks have undergone in the areas alluded to, appear to have affected the trap as well as the adjoining rocks, for we read of the occurrence, under Gairu, of "dark shaly slates with much trap rock similarly disturbed;"[1] and moreover it is evident that in the great tangential squeezing to which the Himalayas have been subjected, comparatively soft rocks in contact with intensely hard ones would fare the worst, and exhibit the most evidence of contortion. If the slates in contact with the trap therefore are in any of those localities more disturbed than the latter, it does not follow that the trap has welled up from below through the broken rocks.

I must not be understood, by the above remarks, to deny the existence of plutonic eruptive rocks, basic or other, in the Sutlej and Biás valleys; indeed the present paper goes to prove the existence of such rocks in a part of the Sutlej valley; but I think it important that the volcanic character of the traps at Darang, Mandi, Suni and Rampur should be recognised; and I suggest the probability of the traps at Gairu and Bihul belonging to this series, because I think, in the absence of fossils, the infra-carboniferous volcanic series, and the upper silurian conglomerate, constitute geological horizons which will afford us important aid in unravelling the geology of the unfossiliferous parts of the Himalayas. When we find trap, cropping out side-by-side with the conglomerate, with no actual evidence of intrusion, the probability seems to me great, that the trap will, upon a careful investigation, prove to belong to the infra-carboniferous volcanic series.

Mr. Bridges Lee, of the Lahore Bar, who has travelled much in Kashmir, Zanskar, and other parts of the North-West Himalayas, and who, I trust, will some day give us the benefit of his observations, informs me that in all places visited by him, the volcanic series invariably come in above the upper silurian conglomerates, and below the carbo-triassic limestones. They afford the geologist, therefore, a definite horizon of much value.

In connection with the subject of the traps it may not be out of place to refer again to the metamorphism of the Jako beds at Simla. This has (see *ante*) been referred to the contact action of acid igneous rocks from above in the form of laccolites; but may it not have been owing to the overflow of beds of basic lava connected with the volcanic activity which prevailed in this region between the close of the silurian and the middle of the carboniferous period? The schists of Jako are believed by Mr. Medlicott to be the representatives of the "shaly slates of Solun,—the black shales at the base of the Krol;"[2] that is to say, to be the representatives of the black infra-Krol shales at the base of the Krol *mountain.* At the Krol, they immediately follow the upper silurian (Blaini) rocks, and are believed to be of lower carboniferous age.[3]

Lavas of the age of those seen at Rampur might well, therefore, have been poured out over the lower carboniferous beds of Jako; and this explanation would also account for what I have very generally observed at Simla, Dalhousie

[1] Memoirs, Geol. Sur., Vol. III, p. 50.
[2] Memoirs, Geol. Sur., Vol. III, p. 34.
[3] Memoirs, Geol. Sur., Vol. XXII, p. 201, compared with p. 161.

and elsewhere; namely, that the dark infra-Krol rocks have very often a strong micaceous glaze on them and a semi-metamorphic aspect.

The supposition that these beds were subjected to contact metamorphism from above before they were disturbed, and before the strata were thrown into their present folds, will help to explain difficulties in local geology which might otherwise prove to be stumbling-blocks. I have already explained (see *ante*) that tangential pressure cannot be urged, in the case of the Jako beds, to explain their metamorphism.

I pass on now to consider the case of the amphibole rocks of the Sutlej valley. The hand specimens collected higher up the Sutlej valley than Rampur, from the localities described in Part I of this paper, have all, superficially, very much the same general aspect; they are very fine-grained, dense, black-looking rocks; but when examined with the aid of a pocket lens, some would be classed as hornblende rocks and some as hornblende schists. An examination of thin slices under the microscope shows that some of these rocks have the composition of quartz diorites.

All the specimens examined by me have much in common with each other; they consist of combinations of hornblende, mica, felspar, and quartz. In some slices the mica disappears; in some, felspar predominates largely over the quartz; in others, the felspar is very sparse and quartz largely takes its place, whilst in some the felspar wholly disappears. The felspar belongs to the triclinic system, and it is a peculiarly glassy hyaline mineral.

The mere abundance of quartz in some specimens does not seem sufficient to take them out of the category of diorites. Mr. Rutley, in his *Study of Rocks*,[1] remarks that "a very large number of diorites are quartziferous;" and Zirkel, in his account of the diorites of the Fortieth Parallel, writes that "in the plagioclase rocks the presence or absence of quartz is not of so much importance as in the orthoclase series; in the former, it often happens that the same deposition is in one place free from, in another poor, and again rich in quartz—a phenomenon which does not occur in the orthoclase rocks."[2]

In rocks that have been subjected to metamorphic action, the presence of quartz has still less significance, as it sometimes results from the decomposition of other minerals such as augite and felspar. Contact with granite, also, has sometimes a silicating influence.

The presence of a fine foliation, which is exhibited by many of the Sutlej valley specimens, moreover, is no proof that these rocks are of sedimentary origin. Foliation in amphibole rocks, as we have already seen (see *ante*), is often the result of lateral pressure. Since the above remarks were written and set up in type, an instance of the metamorphosis of dolerite into hornblende-schist has been described by Mr. J. J. H. Teall, (Q. J. G. S., XLI, p. 133); and it is interesting to note that he also (p. 138) experienced a difficulty in discriminating between the quartz and felspar of the converted hornblende schists of Scourie, similar to that which I experienced in the case of Sutlej valley amphibolites. A similar

[1] 2nd Edition, p. 242.
[2] Microscopic Petrology, p. 84.

difficulty in distinguishing the quartz from orthoclase in a quartz-diorite is noted by Fouqué and Michel Lévy in their *Minéralogie Micrographique*, Part II, Plate XXIV.

I have already, in Part I of this paper, made allusion to several cases in which the fine-grained foliated amphibole rocks of the Sutlej valley appear as intruders in the schists and in the gneissose granite. The Wangtu case deserves, I think, some further comment. A sketch of this example is given at figure 1 of the plate attached to this paper.

This dyke extends apparently for many miles. Above the junction of the Wangar river, there is only one dyke; but between the bridge over the Sutlej at Wangtu, and the Wangar river, this apparently splits up into two parallel dykes.[1] The two dykes are bisected by the Wangar river, and the sketch shows their appearance *in situ*, on the smooth face of a rock composed of gneissose granite, which overhangs the river on the right bank of the Wangar, at its junction with the Sutlej.

A metamorphosed sedimentary rock might conceivably be squeezed up into a crack formed by a rupture of the granite; but this explanation is not, I think, applicable to the present case. The foliation of the hornblende rock runs with the dyke, and is parallel to the bounding walls of granite. The fine lines of hornblende rock (foliated tonalite) between the two dykes, penetrate the granite, diverge from each other, unite again, and again diverge, and terminate in the upper tongue, in a way that seems to indicate unmistakably that the amphibolite ate its way into the granite in a condition of igneous fusion. A like inference may also, I think, be fairly drawn from the behaviour of the two tongues which have eaten their way into the granite at right angles to the course of the dyke from which they emanated.

At figure 2 I have given a sketch of a portion of what seems to me the same dyke which occurs higher up the Sutlej, in the strike of the Wangar dykes, a few miles beyond Wangtu. The sudden way the dyke changed its course and bulged out at the elbow, at the turning point, can hardly be attributed to contortion. The direction of the lines of fine foliation is indicated by the arrows.

When examined under the microscope, the quartz-diorites and amphibolites described in Part II, with scarcely an exception, exhibit structural characteristics which show that they have been subjected to great heat and high pressure. Taking Nos. 18, 21, 26 and 27 as examples, I find that they contain air or gas inclusions, and liquid cavities with moveable bubbles, the bubbles being large relative to the area of the cavities, and indicating considerable contraction of the liquid on cooling and consequently a previous condition of great heat. They enclose numerous microliths containing fixed bubbles, and elongated shrinkage cavities, and microliths that have cracked on cooling. There are also gas inclusions that have deposited mineral matter on cooling, and liquid cavities containing gas bubbles. In short, these slices exhibit structural characters consistent

[1] The dyke crosses the river Sutlej obliquely, and then strikes across the Wangar river and up inaccessible cliffs. It is physically impossible to follow it. The same dyke, or what appears to be the same dyke, reappears several times higher up the Sutlej on the road to Rogi.

with their being plutonic eruptive rocks. I see no reason, on the whole, why they should not be classed as such.

It is possible that some of the more metamorphic-looking beds, as for instance that from which slice No. 22 was taken, may be highly metamorphosed ash, or lava beds, of ancient geological date; and that those of more decided eruptive type may be old lava beds melted down and squeezed into a new place; but speculations regarding the origin of the latter class seem to be out of place; it is enough to know that, even if they had the origin suggested, they must now be classed as eruptive rocks.

Assuming, then, that the dykes of amphibolite in the gneissose granite are of eruptive origin, it would seem that they were erupted prior to the complete solidification of the gneissose granite, and consequently, if the views regarding the age of the latter expressed in my previous papers [1] are sound, it follows that they also are probably of tertiary age. At Narchar, at Wangtu, and between the latter place and Chigaon, the amphibolite or foliated diorite dykes cut through all the varieties of the gneissose granite, but they are themselves cut through by dykes of the white oligoclase granite. Sometimes the oligoclase white granite dykes run a parallel course with the amphibolite or foliated diorite; sometimes they cut straight across it at right angles; whilst at other times they strike up to it, and after having run with it for a little way, pursue their former course.

To sum up my observations on the traps and hornblende rocks; I regard the hornblendic traps at Rampur as metamorphosed lavas of lower carboniferous age. The hornblende rocks and quartz diorites at Pichwara may be either intensely metamorphosed lavas, or more probably eruptive rocks consolidated at no great depth below the surface; but the amphibolites further to the north are of decided plutonic character, and belong to the period of granitic eruption. The uniformly hornblendic character of all these rocks I regard as the result of the great metamorphic action to which they have all been subjected, resulting in the conversion of the pyroxene of basic eruptive rocks into hornblende.

It may be as well, in conclusion, to offer a few remarks on the stratigraphy of the section described in the preceding pages.

At Jutog, and on Prospect Hill (Simla), we have the limestones of the carbo-triassic[2] series let down by a fault against the Krol quartzites seen at Boileauganj. On Jako we have the altered beds of the infra-Krol (lower carboniferous) series. The Blaini (upper silurian) magnesian limstones and conglomerates come in on the flank of Jako, at the Lakri Bazar, and may be traced a far as the Sanjoli Bazar. They are succeeded, on the road to Narkanda, by the Simla slates (middle silurians); but an anticlinal flexure brings down the carbo-triassics again between Fágu and Thiog. The limestones of this series are seen in force between their

[1] Records, XVI, pp. 143, 191, 192.

[2] I use this term in a somewhat vague sense. In the N.-W. Himalayas the carboniferous limestones appear, at times, to run into the triassic series without a break; but in the absence of fossils it is often impossible to say whether, or not, in any given outcrop, the series is complete. On Prospect Hill, for instance, what remains of these limestones are probably wholly of carboniferous age.

outcrop on the Fágu-Thiog road and the Sháli peak. The thick series of limestones seen on the Sháli, I now see no reason to doubt, belong to the carbo-triassic series. Between the Sháli and Simla, there is a sudden transition from the limestones to the Simla slates. The junction is probably a faulted one, and the fault apparently extends to a little north of Fágu, for though the Blaini rocks are seen to the north and to the east of Thiog, they do not crop out, as they ought to do, on the road-side between Fágu and Thiog.

North of Thiog the limestones and slate rocks of the Blaini and infra-Krol series dip under massive quartzites, which doubtless represent the Krol quartzite.

A little beyond Mattiána schistose calcareous beds come in, which I apprehend are highly altered numbers of the Krol series. Somewhere between these beds and Narkanda, I think the existence of a fault must be assumed. Some of the beds here displayed remind me very much of the mica schists of Jako, and it seems open to us to suppose that their metamorphism is due to the causes which have conduced to the metamorphism of the Jako beds; but near Narkanda, we come, on the flank of Hattu, to beds of gneiss.

The microscopic examination of the Hattu gneiss, contrary to my then expectations, did not favour the hypothesis that this rock had an eruptive origin,[1] and I see no reason to class it with the gneissose granites.

But even if we discard the gneiss beds from consideration, the schists exposed at Narkanda, on the road to Kotegarh, are mica schists of an extremely pronounced type, and I do not think they can be younger than of lower silurian age.

Assuming their age to be that here assigned to them, and assuming the existence of a fault between Mattiána and Narkanda, the section onwards may be described as follows. At Narkanda the oldest rocks are found at the point of highest altitude; whilst at Rampur we have the younger rocks occupying the valley of the Sutlej. The dip is north-easterly; and, according to my view, the older rocks dip under younger ones, and we have a regular sequence of rocks between Narkanda and Rampur, beginning with the lower silurians (or cambrians?) at Narkanda, and ending, at Rampur, with the volcanic series of lower carboniferous age.

The Simla slates in this series are probably represented in part, by the micaceous rocks near Kotgarh, and by the thick series of silicious rocks between Kotgarh and Narkanda. The argillaceous element probably gave way in this region to the arenaceous.

At Rampur we find a fault along the axis of a synclinal flexure. The Krol quartzite is again brought up, and the volcanic series follow in inverted order. The quartzites, which to the north of Rampur *follow* the volcanic series (I do not allude to the quartzites intercalated with the traps) represent, in my opinion, the quartzites seen in the southern wing of the syncline between Narkanda and the Nogli stream; but the infra-Krol carbonaceous beds, so typically developed south of the Nogli, have disappeared from the section north of Rampur. These beds may either have been cut off by the fault which, on my interpretation of the

[1] See remarks on slices 51—53, Records, XVII, pp. 60, 61, in which I recorded my conviction, based on microscopical evidence, that these specimens were "metamorphic" rocks.

section, must be placed between the northern boundary of the volcanic series and the quartzites; or they may have thinned out.

The quartzites beyond Rampur are conformably succeeded, first by white mica schists that resemble some lower silurian bedsi n the Dalhousie area; then by mica schists of a pronounced type, and finally by gneissic beds, the foliæ of which are greatly crumpled, and which, I doubt not, are altered sedimentary beds of lower silurian or cambrian age.

According to the view expressed above, the two outer ends of a long synclinal flexure are occupied by the older rocks, with the younger rocks in the middle. The older rocks dip under the younger from Narkanda down to the Nirat outcrop of the gneissose granite; whilst from Rampur to Gaora the rocks are in inverted order, the younger dipping under the older. Between the Nirat outcrop of the gneissose granite and Rampur, the younger rocks have been considerably crushed, especially at Nogli; and the squeeze has been so great that though the volcanic series present, as I believe, a regular sequence from the Krol quartzite at the Nogli up to the fault at Rampur, and from the Krol quartzite at Rampur up to the northern boundary of the volcanic series, yet the Krol quartzite has been brought into contact with the highest beds of the volcanic series and a divergent dip imparted to the volcanic beds on either side of the Rampur fault. That the younger beds in the middle of the long synclinal fold stretching from Gaora to Narkanda should have been subjected to such intense compression is hardly surprising, for they must have suffered, not only from the tangential pressure which produced the synclinal fold, but also from the compression caused by the intrusion of the Nirat gneissose granite.

There is a fault at the end of the southern wing of the syncline, to the south of Narkanda, another along the axis of the syncline at Rampur, and a third between Rampur and Gaora.

Between Gaora and Wangtu no new sedimentary beds come in.

The gneissose granite penetrates the southern wing of the syncline in the middle of the infra-Krol (lower carboniferous) series. In the northern wing it intrudes much lower in the series, appearing in the lower silurians and (?) cambrians.

The quartz-diorite or amphibolite appears in the northern wing of the anticline only, and it evidently belongs to the period of granitic eruption. In my papers in Vol. XVI already referred to (see foot note *ante*) I adopted the view that the gneissose granite was erupted in tertiary times, and I have since seen no reason to modify that conclusion.

In offering the above remarks on the stratigraphy of the Simla and Wangtu section, I am deeply sensible of the danger of framing theories based on road-side observations along a single line, before the neighbouring country is surveyed and mapped by a competent geologist; but as there seems no immediate prospect of this being done, and as the task, whenever it is undertaken, will be a long and laborious one, it may not be out of place to record the impressions that have been left on my mind by the facts at present available.

A modification of the interpretation of the Narkanda-Wangtu section proposed above, that might suggest itself to some minds, is that the infra-Krol rocks,

the Krol quartzite, and the volcanic series were deposited in a basin formed by the denudation of older rocks; but this view is not favoured by the fact noted in Part I of this paper; namely, that there is a gradual decline in the metamorphism of the rocks from Kotgarh down to the black infra-Krol beds. However, were this modification to be adopted, the general features of the section would remain the same as that suggested above; we should still have a broad synclinal fold with the older rocks on the outer flanks and the younger rocks in the middle; we should have the volcanic series and the Krol quartzite compressed together, and ruptured by a fault, the older beds on one side of the fault being brought into contact with the younger beds on the other side, the beds on one side being in inverted order.

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Fibrous quartz, pseudomorphous after crocidolite, from Griqualand, South Africa.

PRESENTED BY MR. W. THEOBALD.

Two small pieces and some fragments of the meteorite that fell near Sabetmahet village, at Mutfiura-ghat (N. Lat. 27° 35′, E. Long. 82° 7′), 11 miles N. W. of Balrampur, Gonda District, Oudh, on the 16th August 1885. The weight of the two pieces and fragments is 2·84 grammes.

FROM THE DEPUTY COMMISSIONER OF GONDA, OUDH.

A specimen of galena, from the Thandiana range, Abbottabad Tahsil, Hazara District, Punjab.

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MAPS.

Map of the United States exhibiting the present status of knowledge relating to the areal distribution of geologic groups. (Preliminary compilation.) Compiled by W. J. McGee. 1884. THE COMPILER.

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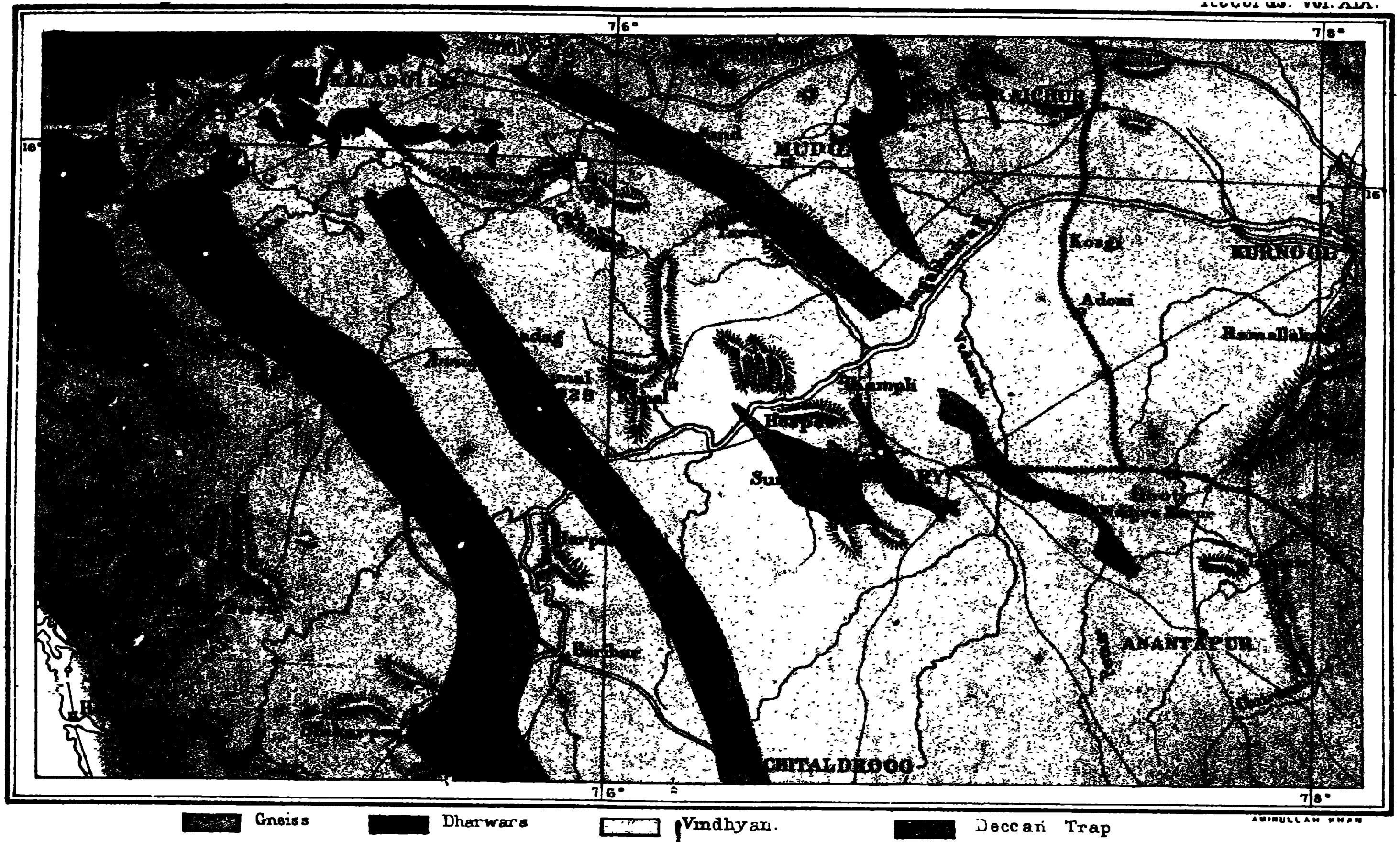

SKETCH OF THE GEOLOGY OF BELLARY AND ANANTAPUR DISTRICT
Scale 1 Inch = 32 Miles.

RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 2.] 1886. [May.

Notes on the Geology of parts of Bellary *and* Anantapur Districts, *by* R. B. Foote, F.G.S., *Superintendent, Geological Survey of India.* (With a map.)

Definition of area.

The tract of country here described has in plan a rough resemblance to an hour-glass lying on its side, the length of the hour-glass being 88 miles, its smallest width 15 miles, where traversed by the Haggari river (or Vedavati, of the map); and its greatest, at its western end, 38. The fiscal divisions included within this irregular area are,—the greater part of Gooty taluq, the southern half of Bellary taluq, nearly the whole of Hospett taluq, the whole of the Sandur State, and the north-eastern corner of Kudlighi taluq beside the northernmost extremity of the Mysore territory.

Principal rock groups.

Three principal groups of rocks occupy the area above defined. The youngest, or third, being formed by the alluvia of the Haggari, the Tungabhadra, and their tributaries. They cover a small area, and are of very small importance.

Alluvia.

To the alluvia may be reckoned some gravel formations of no great extent and small thickness, which are scattered here and there over the surface of the older rocks.

Dharwar system.

Gneissic system.

The second group consists of a very important series of schistose rocks which occurs in bands overlying the gneissic rocks, which latter constitute the first and oldest group and cover by far the largest area.

Dharwar or schistose system.

The second or schistose group was formerly regarded as belonging to the great gneissic system of South India, and described as such (*vide* Memoirs, Vol. XII, pp. 38—54); but since then a fuller examination of several of the bands has yielded evidence amply justifying their separation into a distinct system. As already shown in my memoir on the geology of the South Mahratta country, just referred to, and in my paper on a traverse across the Mysore gold-fields (*supra* Vol. XV, 1882), a considerable number of bands of similar character cross the gneissic

area both north and south of the tract now under consideration and cut it up into similar but, as a rule, considerably wider bands.

Number of bands under report.

Eight such bands have been recognized so far and named after the principal towns standing within their limits; but we are only concerned with three in the Bellary-Anantapur country so far as it has as yet been surveyed. These, taking them from east to west, are:—1, the Pennér-Haggari band, an unquestionable extension of the great Hunugunda band in the Raichur Doab;[1] 2, the Sandur hills band, including the Copper hills south of Bellary town; and 3, the Dambal-Chicknayakanhalli band, which runs through the Hadagalli and Harpanhalli taluqs (the most westerly extremity of Bellary District), connecting the schistose rocks of the South Mahratta country with those of Mysore. Another band of the schistose rocks which however does not touch the Bellary territory, but lies well to the west of it, deserves mention, and this is the great Dharwar-Shimoga band, the broadest and most important of all as far as yet known.

Name of Dharwar system why given.

The schistose rocks forming this band near Dharwar, and still more in the central part, near Shimoga and Honnali (Mysore), show much less metamorphism than elsewhere generally; and it was here that I was for the first time forcibly impressed by the necessity of trying to establish a separation between these old schists and the great granitoid gneiss system of South India. For this reason, and from the fact that this band shows the greatest development of the old schists, I have proposed to call the new system they form the Dharwar system.

At the time when I wrote my memoir on the South Mahratta country, I had no positive evidence of the unconformable superposition of any of the schist bands over the granitoid gneiss of the Southern Deccan, and was inclined to think that the schists might possibly belong to more than one series and in parts be intercalated with granitoid beds, as in several sections in the Raichur Doab they appear to dip under the granitoid rocks. The examination, however, of the Kolar gold-field convinced me that the schist series here forms an undoubted synclinal basin sunk in a fold of the underlying gneiss. The study of the Sandur hills since then has satisfied me that the schists, or, as they should henceforth be called, the Dharwar rocks, rest on the granite gneiss with marked unconformity. Further acquaintance with the different bands of the Dharwars leads me to believe that they all belong to one system, which was formerly very widely developed over the peninsula. How widely has yet to be determined in many parts, but it is certain that they were once represented all over the Central Deccan and southward as far as the Kolar gold-field, and in all probability as far south also as the north-western corner of the Nilgiri massif.

Additional interest attaches to the Dharwar system from the fact that to it belong nearly all the gold-fields at present known in the Peninsula, notably those of Kolar, Wynád, Honnali and Dambal, besides others less known in Mysore and the Bellary, Dharwar and Belgaum Districts.

[1] No place of any importance stands on this band within the limits of the Gooty and Bellary taluqs, but it crosses both the Haggari and Pennér rivers.

Origin of the schist bands.

The bands of schist by which the Dharwars are now represented in the peninsula are the remains of great foldings which took place long anterior to the deposition of the lower-Vindhyan rocks forming the Kaladgi and Kadapa basins. A consideration of the section across the several bands where they emerge from under the southern edge of the Kaladgi basin will show at once that the upheaved Dharwars had undergone immense denudation before the deposition of the Kaladgi rocks commenced. The jaspery hæmatite beds of the Dharwar system furnished the bright coloured jasper pebbles which are so striking a feature in the basement and other conglomerates of the lower-Vindhyan rocks.

The force which caused the great crumpling of the Dharwar rocks had of necessity also much effect on the underlying gneissic rocks, and in various places induced a parallelism of folds which produces great semblance of conformability. The section of the gneiss rocks exposed south of the southern end of the Sandur band shows the gneiss to have been affected by an anterior process of crushing from pressure acting in a more or less east and west direction. This is noteworthy as it shows that the peninsula was affected at no less than four periods by great approximately east to west, or west to east, thrusts, the two already noted and two later ones by which the Kadapa and Karnul rocks were respectively crumpled up into the great foldings they now show. Of these the last would seem to have been much the least energetic.

A brief description of the chief petrographical characters of the gneissic and Dharwadian rocks will suffice for the present, the full description being reserved for the final memoir on the geology of the Bellary-Anantapur country. By the time that has to be written, it is hoped that many of the more important rocks will have been examined microscopically.

Intrusive rocks.

The intrusive rocks penetrating the gneiss and the Dharwars are of considerable importance, and often form marked features in the geological landscape. Two ordinary forms of intrusive rocks were noted, granite veins and trap dykes, which will be described further on. Another intrusive rock of great interest is a tuff-agglomerate of undetermined age, which forms a so-called "neck" piercing the gneiss close to Wadjra Karur, a famous diamond-yielding locality 10 miles south of the Guntakul railway junction. This will be described further on. The external resemblance of the agglomerate to the matrix in which the famous Kimberly diamonds occur, has caused it to be very elaborately prospected, but unfortunately without any satisfactory result.

I.—The Gneissic Rocks.

By far the greater part of the gneissic area is occupied by highly granitoid rocks, which are also far more conspicuous than the well-foliated gneisses. Excepting in the various groups of rocky hills which are scattered about the Bellary-Anantapur country, the gneissics are generally very little seen owing to the great and continuous sheets of regur which form so characteristic a covering of the great plains in this part of the Deccan. In many of the few outcrops found within the area of the regur spreads the gneiss is in too advanced a state of decomposition to allow of anything but the roughest determination of its nature.

Speaking generally, the gneissic area within the tract under review is occupied by two principal varieties of granite gneiss,—the one a fine or medium-grained reddish or grey variety which occurs in the eastern part of the tract, the other a coarse-grained often strongly porphyritic variety which forms the mass of the rocks in the central and western parts. Both are markedly felspathic in composition.

Two principal varieties of granite gneiss:

Some of the fine-grained pink varieties occurring in the eastern parts are so homogeneous in structure as to be hardly distinguishable from felsites. The rocks here have undergone an extra degree of metamorphism and have lost nearly all traces of their original lamination, so that they are often very hard to distinguish from the veins of intruded granite. They are greatly cut up by a system of north and south jointing, which is often so largely developed as to simulate true bedding very strongly.

a, fine grained variety.

The most remarkable accessory mineral in this part of the gneiss is pistacite which occurs very largely in veinlets and in films lining the sides of planes of jointing. It is common, too, in grains in the mass of the rock. Where the rock is much weathered, as it often is, the country is thickly strewn with fragments showing brilliantly yellow-green pistacite, contrasting in a very pleasing way with the red or bright-pink felspar.

This pistacite is specially characteristic of the granite gneiss at and around Maddikeri (Muddykerra), a few miles north-east of the Guntakul railway junction. Much pistacite in films occurs also on the joint planes in blocks of diorite in the great trap-dykes of this region.

This pistacite would appear to be the vivid green mineral Newbold so often notes in his paper on this part of the Deccan as "Actinolite." I did not see a single crystal or speck of true actinolite in the Bellary-Anantapur country; the pistacite, on the contrary, is of very common occurrence almost everywhere. It is less common, but by no means uncommon, in the very coarse porphyritic, variety of granite gneiss so largely developed to the westward of the Pennér-Tungabhadra band of the Dharwars, and which constitutes the typical Bellary gneiss.

The porphyritic gneiss is admirably displayed in the Fort and North hills at Bellary itself. The rock is largely traversed by great joints, by which it is cut up into great masses. One of the most constant of the master joints is a nearly horizontal one which often gives the scarps an almost artificial mural appearance.

b, porphyritic variety.

The weathering action of the atmospheric agencies attacks the various blocks along the joint planes, and penetrates very equably in most cases. In some parts of the rock, however, there is a decided tendency to concentric sphæroidal weathering; and where this is the case, the rate of decay appears to be very much greater than elsewhere.

The foliation or lamination of the rock is generally obscure, but occasionally shows well. The bedding of the rock is rarely recognizable on the spot, but is often very clear when seen from a distance.

The freshly-broken granite gneiss is generally of grey or greyish pink or purplish colour, and weathers pink or brownish-pink. The prevalent felspar is a pink orthoclase.

Granite gneiss, very strongly resembling the Bellary beds, occurs east of the Haggari river in the Karaka Mukalu (Curraka Mookaloo) and Budihal hills near Uravakonda, and also to the N-W-by-W in the Daroji hills, and both sets may very reasonably be regarded as extensions of the Bellary beds.

The fine granite gneiss hills north-east of Bellary, known as the Peacock hills, as also the picturesque group of rather lower hill around Kurgodu consist of a finer-grained rarely porphyritic variety of grey granite gneiss. In colour and the tendency to be cut up by planes of jointing into great masses, both varieties agree closely. Two of the most remarkable tracts occupied by granite gneiss are the environs of Hampi and Anagundi on the banks of the Tungabhadra, and the hilly country around Gudikotta, south of the Sandur hills. In both tracts the peculiar features of a very wild rocky hill region are seen to perfection.

Tracts of granitoid gneiss.

The Hampi tract is the more interesting, as it includes the extensive ruins of the old Hindu city of Vijayanagur, destroyed in 1564, after the great defeat at Telikota of Rama Raja by the allied Sultans of Bijapur, Golconda, Daulatabad, and Berar. A remarkably beautiful and instructive panorama of this granite gneiss tract is to be obtained from the summit of the Martanga Parvatum, a high temple-crowned rock rising close to the gorge of the Tungabhadra. The tremendous ruggedness of the granite gneiss hills forms a very remarkable contrast to the great fertility of the narrow valleys which run between the hills.

As already mentioned, typical schistose gneisses are very little developed in the country here dealt with. The most noteworthy example of them is a narrow band lying between the porphyritic granite-gneiss band of Bellary, and the range of hills culminating in the Copper mountain to the south. The gneisses are badly seen, being much obscured by cotton soil on the north, and on the south by an extensive talus of hæmatite and other schists of Dharwar age washed down from the Copper mountain. The principal variety of gneiss here seen is a typical, well-foliated quartzo-hornblendic rock. Its relations to both the granitoid gneiss and the overlying Dharwar rocks have yet to be worked out, no section having as yet been found in which they are exposed in juxtaposition. Schistose gneiss is also developed to some extent in the valley of the Pennér and to the south and east of Wadjra Karur.

Schistose gneiss.

II.—The Dharwar Rocks.

The rocks forming this system are very varied in kind, but schistose varieties predominate strongly, and give a marked character to all the tracts they occupy. The general distribution of the Dharwars in bands has already been amply illustrated; and it has been pointed out that, so far as at present known, three of the great bands traverse the Bellary-Anantapur country, of which the two eastern-most lie within the surveyed area here described. These are (*a*) the Pennér-Haggari and (*b*) the Sandur and Copper hills bands.

a. The Pennér-Haggari band has been traced from the south bank of the Pennér, a little east of Udaripi Drúg (Oodorpee Droog of Sheet 59) across the Gooty taluq north-westward into the Bellary taluq, and on for a distance of 12 miles as

The Pennér-Haggari band.

far as the south end of the Sindygerry hills which it forms. From its geographical position there cannot be the slightest doubt that it represents the extension of the great Hunugunda schist band which crosses the Raichur Doab, and runs through the Hunugunda taluq of Kaladgi District (Bombay Presidency), and is lost to sight under the great conglomerates forming the base of the Kaladgi basin. Except in the very broken and rugged tract which occurs on both sides of the Pennér, the rocks forming the Pennér-Haggari band are very much obscured by the great spreads of regur which cover the plains of the Gooty and Bellary taluqs. Near the Pennér the prevalent rocks are chloritic schists of dark-green colour, which form several minor ridges. The schists have been highly metamorphosed, and are traversed by several very large dykes of greenish or bluish-black diorite. A band of hæmatitic schist shows to the east of Pedda Paipully (4 miles east of Uravakonda), where the band is at its narrowest, having been very greatly denuded. Further to the north-west hornblendic and hæmatitic schists appear, and the chloritic schists have given place to a black trappoid hornblendic rock which looks very much like a contemporaneous trap, partly converted by pressure into a hornblendic schist. Still further north-west, coarse hornblendic schist forms a low bare ridge 6 miles north-west of Uravakonda. To the north of it is a band of the trappoid rock, and to the north-north-west is a low ridge the crest of which consists of red jaspery hæmatite rock with interbedded laminæ of fine white and grey cherty quartzite. On the south side of the ridge is a show of chloritic schist. Chloritic schists, with a band of hæmatite forming the crests of the Chelgurki (Chailgoorky) and Joladarashi hills are the only members of the Dharwar series seen penetrating the regur spread as far as the right bank of the Haggari. There are no visible outcrops in the bed of the Haggari, and on the left bank the regur spread masks everything for several miles. A ridge of hornblendic trappoid rock, probably belonging to the Dharwars, protrudes over the regur to the north of the railway 4 miles east of Bellary. The northernmost part of the band yet surveyed shows chloritic schist south of Korlagundi (Kortagoondy of Sheet 58), and hornblendic schist north and north-west of the village, while a broad spread of black trappoid rock caps the watershed to the south-west and west.

Except at the south end of this band, close to the Pennér, the boundaries are everywhere concealed by cotton soil or other superficial deposits. Where seen, the basement bed, a gritty schist, rests on the very rugged surface of the granite gneiss. The schist laps round many boss-like inequalities of the gneiss and forms a very rugged boundary in consequence. Too little of this band is exposed in the Gooty and Bellary taluqs to enable one to explain as yet the position it occupies with reference to the underlying gneissic rocks. Near the Pennér it certainly appears to hold the position of a synclinal fold, sunk among the gneissic rocks, like the central part of the Kolar gold-field band. This structure, however, can hardly obtain throughout the whole length of the band, and, very probably, many parts owe their preservation to their having been faulted down by long lines of dislocation. This band nowhere exceeds 5 miles in breadth, but is certainly of considerable thickness, the beds composing it being tilted up vertically in parts, and generally showing very high angles of dip.

b. This band of the Dharwar rocks is far the most interesting geological feature in the Bellary country, and deserves very close study for two reasons: one being that its relations to the underlying gneiss are exposed in various sections; the other, that it shows a great thickness of rocks of very varied character thrown into varied positions of great interest, and by no means easy of explanation at first sight. The area occupied by this band is by no means easy of definition in plan, and I must here refer the reader to the map; he will there see that the band consists of two roughly parallel divisions united by a short cross belt in the middle. The two divisions run nearly north-west and south-east, the western or Sandur hills division forming a synclinal basin in shape like a very pointed leaf, the stalk being the southern end. The eastern, or Copper hills, division, the structure of which is much less obvious and has not been completely worked out, also appears to form a narrow synclinal fold, at least in its southern half. The former has a length of about 35 miles;[1] the latter, so far as traced, measures 29 miles, from its south-eastern extremity, 7 miles S-S-E of Bellary. The two divisions include the highest elevations in the district, the eastern having for its culminating point the Sugadevabetta or Copper mountain, which attains the height of 3,148 feet above sea level, while the Sandur basin is surrounded by two high ridges which unite to the south. Of the two, the western appears to be rather the higher, and attains an elevation of 3,256 feet at Ramandrúg and is probably 100 or 150 feet higher still a couple of miles to the southward. The height of the two ridges is very nearly equal, and continues so to near the northern extremity of the synclinal, when the ground sinks rapidly to the north. As seen from a distance from nearly all points the mountain mass seems to form a great plateau, and no one would, in looking from a distance, ever imagine the existence of the great central valley. The valley is naturally accessible only by three passes, one at the north, close to Hospett, called the Ramanagundi, and the two gorges cut by the Narihalla river through the east and west ridges respectively. These two gorges afford the best sections of the central part of the synclinal, and are very beautiful approaches to the town of Sandur, which lies very nearly in the middle of the great central valley. Newbold, in his paper on the Sandur state,[2] gave a very graphic description of the two passes.

The Sandur and Copper hills band.

Sandur valley entered by three passes.

The section in the western gorge, or Oblagundi, is considerably shorter than that in the eastern one, or Bhimagundi, but is a better one as the rocks are much more clearly exposed. Owing to the great drought prevailing in the beginning of last year, 1885, I was unable to camp in the northern part of the Sandur valley, and did not therefore succeed in making as complete a survey of it as necessary fully to understand its structure. Considerable inversion of the beds on the eastern side of the valley has taken place, and I am not quite certain how far this

[1] The extreme north point lies several miles north-west of the Tungabhadra in the Nizam's Territory, and has not yet been visited.

[2] This is a very interesting paper, and well worth perusal, for the little Mahratta State has a more interesting history than many larger ones in the peninsula.

inversion has extended westward. What are probably the uppermost axial beds of the synclinal appear to be dipping under what are really much lower members of the system ; the following section across the synclinal through the two gorges must therefore be accepted as preliminary only. Entering from the west by the Oblagundi gorge, and proceeding north-eastward, the following succession of rocks is passed over; the length of the section is a trifle over 8 miles.

The Sandur section.

1. Schist, dark-green, hornblendic. ?
2. Schist, gritty, brownish green.
3. Hæmatite rock, very thick.
4. Schist, green.
5. Hæmatite rock.
6. Schist.
7. Hæmatite rock.
8. Argillite schist, ferreous,—red, brown, and chocolate.
9. Hæmatite rock ; *the gorge bed.*
10. Trap, contemporaneous.
11. Hæmatite rock.
12. Trap, contemporaneous.
13 Clay schist.
14. Trap, contemporaneous. Sandur flow.
15. Schist. } Devadara hill beds.
16. Hæmatite rock and schist. } Devadara hill beds.
17. Schist. } Devadara hill beds.
18. Trap, contemporaneous. Hoshalli flow.
19. Hæmatite rock.
20. Schist.
21. Hæmatite rock. Bhim Tirth bed.
22. Schist.
23. Hæmatite rock, *the gorge bed.*
24. Schist, with contemporaneous trap.
25. Hæmatite rock.
26. Schist.
27. Hæmatite rock.
28. Schist.
29. Hæmatite rock.
30. Schist, with contemporaneous trap.
31. Hæmatite rock. Long cliff bed.
32. Schist, with contemporaneous trap.
33. Hæmatite rock. Brecciated bed.
34. Schist.
35. Hæmatite rock. Ettinahatti bed.
36. Trap, contemporaneous.

As yet it is not possible to correlate the beds on the two sides of the synclinal, but this may be possible when they shall have been followed up round the southern extremity of the basin.

The great hæmatite beds give rise to many steep mural scarps, several of which along the eastern side of the eastern ridge are of great height and length, and from their vivid red colour form a splendid contrast to the patches of rich green forest remaining at their base.

Papanaykanhalli section.

Another instructive section of the eastern ridge was studied in the ravine opening out northward, about half-way between the Bhimagundi gorge and the north-western end of the ridge near Hospett. I will call this the Papanaykanhalli ravine, after the village nearest to it. Proceeding downwards from south to north, the following series was crossed :—

15. Hæmatite rock, very jaspideous, much crumpled and brecciated.
14. Trap ?—a greatly decomposed earthy rock of purple colour.
13. Hæmatite rock, very thick, brecciated with small quartz veins.
12. Trap?— an earthy green and purple rock.
11. Schists, argillites ?—chocolate, and sometimes lavender coloured.
10. Schists, green chloritic ? - a great thickness.
9. Hæmatite rock, a thin poor bed.
8. Schists, green.
7. Trappoid rock, black.
6. Schists, dark, nearly vertical.
5. Slates, greenish, badly cleaved.
4. Schists, green, silky texture.
3. Schists, green, coarse.
2. Hæmatite rock, poor.
Gap.
1. Schist, dark.
Talus.

Bed 15 forms the western scarp of the ridge overhanging the central valley opposite to Hunshahuti.

Ramandrúg section.

The section across the western ridge at Ramandrúg obtained by following the ghât road leading up the western slope shows the following series :—

8. Schists.
7. Hæmatite rock, rather shaley in parts.
6. Schists, chocolate to red in colour, very ferreous.
5. Hæmatite rock. Prospect point bed.
4. Schists, dark greenish and blackish, passing into clay slate locally.
3. Hæmatite rock.
2. Schists, dark and light green.
1. Quartzite, much altered.
Gneiss.

On the eastern slope the succession of rocks is continued as follows in ascending order stratigraphically, but descending order topographically :—

9. Hæmatite rock. "Red-cliff" scarp.
10. Argillites.
11. Trappoid rock, black, contemporaneous.
12. Hæmatite rock, in first low ridge, shaley in parts.
13. Trap, dark-green, contemporaneous.
14. Argillite, red, ferreous.
15. Trap, pale-green.
16. Schists, green ?—hornblendic ?
17. Trap, contemporaneous.

The eastern section is by no means clear, the slopes being very largely hidden by hæmatite debris.

Correlation of the western sections.

As before mentioned, it is not yet feasible to correlate the several formations on the opposite sides of the synclinal, the section at the northern end being very obscure and unsatisfactory, while that at the southern end has not yet been studied in detail. Some of the leading beds in the Ramandrúg section may, however, be identified with some in the Oblagundi gorge, the western end of the Sandur section. For example, the lowest hæmatite of the Ramandrúg section (bed No. 3) corresponds with bed No. 3 of the Sandur section. "Prospect point" hæmatite bed on Ramandrúg can easily be traced by the eye along the flank of the ridge into the Oblagundi gorge, where it forms bed No. 7. No. 9, the "Red cliff" hæmatite bed of Ramandrúg, continues southward and forms the gorge bed No. 9 of the Oblagundi gorge. The hæmatite No. 12, and the contemporaneous trap No. 13 of the Ramandrúg section correspond with Nos. 11 and 12, respectively, of the Sandur section. Beyond these I am not prepared as yet to regard any correlations as established.

North end of synclinal basin.

The extreme north end of the eastern ridge appears to be cut off by a fault on the north side of the Hospett hill, but unfortunately the base of the hill is completely obscured by talus and thick soil, so the fault is hard to prove.

The north extremity of the western or Ramandrúg ridge is also very obscure from the great hæmatite talus covering its sides. The hæmatite beds are inverted, and are cut off to the north by a fault, or, what is less probable, die out abruptly. Anyhow I could not trace them across the bed of the Tungabhadra, where the Dharwars are represented only by massive hornblendic rock. These hornblendic rocks form a great barrier in the river, and give rise to a formidable rapid when the river is at half flood. It is quite impassable by fording, and no boat was to be got, so I was unable to follow the rocks into the Nizam's territory across the river. The Dharwars are seen to form some low hills which stretch away several miles to the north-west.

Hæmatite taluses.

The hæmatitic talus, which is almost everywhere a very remarkable feature along the base of the Sandur and other hills of Dharwar age, completely conceals the junction with the gneiss for a distance of 13 miles along the western slope.

The boundary then trends a little more to the south and gets away from the hæmatite talus, and the basement beds can be seen resting on the rugged surface of the gneiss and lapping round the various inequalities. The basement beds consist of very coarse, gritty, hornblendic, micaceous and chloritic schists, passing here and there into coarse, gritty quartzite sandstone, or, more rarely, into coarse, gritty talcose schist. Owing to the hummocky character of the underlying granite-gneiss surface, the edge of the boundary between it and the Dharwars is extremely rugged. This feature cannot be shown, however, on a small scale map.

Old talus forming a terrace.

Much less hæmatite talus is seen along the southern slope of the Sandur basin than on the eastern and western slopes, but there are some very interesting remains of an older talus forming a terrace at an elevation of 150 to 200 feet above the present base of the slope. This terrace, which is very sharply cut, and a conspicu-

ous feature in the landscape especially as seen from the north-west and west, extends for about 3 miles along the side of the Komaraswami (Comarsamy) plateau, as this part of the Sandur group is called after the famous temple of that name which stands in a ravine on the northern side of the plateau. The greatest width of the terrace is about ¾ of a mile, and it slopes up gently but increasingly northward. The thickness of the hæmatitic mass composing the terrace is not great, and where seen along the edges nowhere exceeds 15 or 20 feet. The mass is much lateritized by the action of percolating water, and shows much pisolitic structure and vermicular tubulation, but was purely hæmatitic as far as my examination went. It rests upon a highly decomposed surface of granite gneiss. It is evidently of great age, as two outliers of it occur on detached hills which have been separated from the main mass by denudation extending to a depth of considerably over 100 feet into the underlying granitoid rocks.

South end of synclinal.

The extreme south end of the Sandur synclinal shows thin beds of hornblendic and micaceous schists, gritty ferruginous clay-schists, and poor hæmatite rock (almost a quartzite), resting unconformably on massive banded grey granite gneiss, which has, as usual, a very rugged surface.

The Madras Government has leased the greater part of the forest tract on the Sandur hills from the Rajah, and stopped all jungle fires. Thanks to this, the hills yielded an inexhaustible supply of jungle grass which was the only food for cattle procurable in that part during the terribly dry months before the advent of the south-west monsoon of 1885.

The Intrusive Rocks.

The intrusive rocks form no mean feature in the landscape of many parts of our area, and cannot be overlooked even in a brief description of its geology. They are of two classes, trappean and granitic, the latter being in all probability the older in all cases.

Granitic veins.

The granitic intrusions are of much less magnitude and importance than the trappean, and much less widely distributed. The principal centre of occurrence for the former is in the rocky hills lying west of Gooty; they are not well marked as a rule. Here the granite gneiss, and further south the banded hornblendic gneiss, is greatly cut up by red pistacite granite in very irregular veins of all sizes.

The granite is a ternary rock consisting of white quartz, red or pink, orthoclase and bright green pistacite (epidote). Besides the numerous red granite veins, the banded hornblendic gneiss near Wadjra Karur is much seamed by small and very irregular veins of a close-grained grey or drab, veins of which are often anastomosing to a remarkable extent. *Query*—Are these not veins of segregation ?

Pegmatite veins in gneiss

In the coarse varieties of granite gneiss in the western part of our area, intrusive granite veins are not at all common, but veins of pegmatite derived from the gneissic mass by segregation are very common, but too small and irregular, as a rule, to demand any notice.

A few veins of good size of intrusive granite were noticed in the Dharwar area at the spot where they are exposed in the bed of the Tungabhadra. They are rather pegmatitic in texture and composition but well-defined. Many parts of the surface are highly polished by the action of the water during the south-west monsoon floods.

in the Dharwar system.

Trap-dykes are of very common occurrence throughout our area, and, with very few and unimportant exceptions, consist of dark-green or blackish diorite, which is generally homogeneous in texture, but now and then markedly porphyritic. Their prevalent strike is N-W-by-W, S-E-by-E, with slight variations to north and south. Dykes having a N-W to S-E course are not common, and the same may be said of those having an E. to W. course. Only a moderate number of dykes have a north-easterly course, and only one or two have a north and south strike. A great many more exist than have been mapped, their courses not being traceable under the great spreads of cotton soil. It is very common to come across a block or two of trap peeping up through the regur, but it is impossible, unless there is a fair outcrop, to ascertain the strike and dimensions. There are four centres where the number of dykes is great:—

Trap-dykes.

(*a*) The hilly tract between Gooty and the eastern edge of the great Bellary plain.
(*b*) The hilly country on the banks of the Pennér at Udarapi (Ooderpee) Drúg.
(*c*) The Copper hills synclinal ridge, and the gneissic tracts on both sides of it.
(*d*) The gneissic tract between the north side of the Sandur synclinal basin and the Tungabhadra.

Some few dykes cut through the Dharwar rocks as well as the gneiss, but they offer no special characters by which to infer that they belong to either series, except in two cases where they are very markedly different from the normal type of the old dykes. In both these cases the abnormal trap is so highly charged with blebs of a creamy white felspar in a dark green matrix, that the rock at a little distance strongly resembles a coarse pudding-stone. Three large dykes of this blotchy type occur close together in the centre of the Pennér-Haggari band of Dharwar rocks, 4 miles to the south of the Virapur station of the Madras Railway. A tiny outcrop of a precisely similar trap occurs at Chaganur, on the left bank of the Haggari, 8 miles E.-by-N. of Bellary. Several of the larger dykes form at intervals striking black ridges which rise from the plain to a considerable height, sometimes as much as 200 to 300 feet. No accessory minerals of any interest were observed in any of the dykes.

Blotchy trap.

Quartz Reefs.

Quartz reefs, though not so common as in the neighbourhood of Anantapur and Gooty, are by no means wanting in our area; they mostly run N-W-by-W to S-E-by-E. A very fine triple set crests a big hill immediately north of the Pattukotta Cheruvu Railway station between Goy and the Guntakul junction. Two very conspicuous reefs form the crests of the Tella Konda and Ragulpâd ridges south-east and south-west, respectively, of Wadjra Karur. Two important and conspicuous reefs form big ridges to the south-west and west of Bellary. A

group of three reefs of large size rises to the east of Kamalapur in the Hospett taluq, and forms the crest of two big hills. And, lastly, a very large and thick reef shows in Niddagurti hill, 8 miles S-W-by-W of Sandur town, and extends 6 or 7 miles W-N-W, rising into a considerable hill in the middle of its course.

The Tuff-agglomerate at Wadjra Karur.

Wadjra Karur has for so long a time been famous for its yield of good diamonds that it has naturally attracted the attention of diamond merchants as well as speculators. All have been anxious to find out whence the diamonds came; but the question would not and could not be answered. A remarkable formation of agglomerated tuff appears in a "neck," piercing the highly epidotic granite gneiss lying west of the town. This tuff bears a striking resemblance to some of the matrix rock at the diamond-diggings at Kimberley in South Africa, and attracted the attention of somebody having a knowledge of the African mines. A company was thereupon got up to prospect it thoroughly, and this was very ably carried out by Mr. Copley, an experienced diamond-digger from Kimberley. In partnership with Mr. R. G. Orr (the very enterprizing senior partner of the large Madras jewellers' firm of P. Orr and Sons) and others, Mr. Copley made deep sinkings in different parts of the neck and passed a very large quantity of promising-looking material through the very perfect washing machinery set up. Unfortunately the results were *nil*. This is much to be regretted; for, had diamonds been found in the tuff, it would have settled the question as to at least one original source for them in South India. Mr. Orr and his partners were worthy of every success for the very spirited and thorough way they went to work in the matter.

The "neck."

Diamond diggings.

Mr. Copley was most courteous and obliging in allowing me to see and examine all his workings and to take whatever specimens I wished. His prospecting, though unfortunately so resultless to himself and his partners, was a great blessing to a large number of labourers who could have got no other work, because the terrible drought had stopped all agricultural work early in 1885. I made a very careful study of the tuff "neck," and its surroundings, but could obtain no evidence whatever as to its geological age. This is much to be regretted, as it is so far the only example of the kind known in South India. The neck is of considerable size and covers an area of several acres, but is much obscured by gneissic debris. The tuff being much softer than the surrounding gneiss, its surface has been worn into a hollow forming the head of the little valley across which a little further S.-E. stands the small town of Wadjra Karur. Here and there the tuff assumes the character of an agglomerate, enclosing a moderate number of small and large angular masses of the epidotic granite gneiss through which the "neck" was protruded. Enclosures of no other rock were seen.

Not the faintest particle of carbonaceous matter is to be seen either in the tuff or the granite gneiss, and it is impossible not to attribute to this the absence of diamonds. Had the "neck" passed through highly carbonaceous shales as was the case at Kimberley, diamonds would probably have been formed in abundance.

Absence of all carbonaceous matter.

That diamonds have been and are from time to time found at and around Wadjra Karur cannot be doubted, unless it be assumed that "all men (of that ilk) are liars." I had at least half a dozen spots in the adjoining fields pointed out to me where fine stones had been found by men now living in the town, some by pure accident, others by men of Bohemian tendencies, who make a point of wandering over the country after every fall of rain in the hope of seeing the glint of a diamond washed clean by the rain.

No traces of old gravels.

I devoted some days to wandering over the neighbourhood looking after traces of old gravels from which the diamonds might have been derived, but was utterly unsuccessful whether in the bare gneiss country east and south of the place or on the regur spread north and west of it. Even in the old diamond-diggings west of the town I had no better success. I only got three or four really water-worn pebbles of dirty reddish-brown quartz which might have come accidentally from any neighbouring stream. All else was angular or weathered gneiss debris derived from the immediate neighbourhood. I had hoped I might get evidence of the former existence of gravels formed by disintegration of old conglomerate beds which formerly existed in the neighbourhood, for it requires no very great stretch of imagination to conceive that the conglomerates of the Kadapa and Kaladgi formations once covered the area now intervening between their respective basins and extended even much further south. The basement conglomerate of the Karnul series which is known to contain diamonds in various places might also have extended over the Bellary and Anantapur plains in former geological periods and been denuded away, leaving a few diamonds behind as their very last remains. No proof of this was obtained, and the question as to whence come the Wadjra Karur diamonds remains unanswered. I did not accept only the mere statements as to the finding of diamonds there made to me personally by the local natives, but was assured both by Mr. R. S. Orr, and by Mr. Matthew Abraham of Bellary, well known as a diamond merchant and cutter, that they have repeatedly within the last few years bought good stones found there or close by. According to the statements made in the Bellary District Manual,[1] the diamond industry was far more important during last century than at present. Mr. R. S. Orr has now a Wadjra Karur diamond for sale valued at more than £10,000. It is a large and remarkably fine stone.

Soil and superficial deposits.

There is nothing of novelty or special importance to say of these, so I will defer their description for the final memoir.

Economic Geology.

The economic geology of our tract is of very small interest and importance. Nothing but building stone appears to be raised now. The old iron industry is nearly extinct. Some hæmatite is however still quarried at the north end of the northern ridge and smelted at Kamalapur to be converted into the large iron

[1] Written before the division of the old Bellary District, by Mr. John Kelsall of the Madras Civil Service.

boilers used there and elsewhere in the district for boiling down sugarcane juice. Should the forest conservancy, now energetically carried out, succeed in re-a-foresting the Sandur hills, and reducing the present high price of charcoal, it is possible that the old industry in the way of charcoal iron might revive, the supply of splendid hæmatite ore being absolutely unlimited.

No use is made at present of the splendid ribbed jaspers so largely developed in the north-eastern ridge of the Sandur hills, but they would supply exquisite material for Mosaic work in "pietri duri," as would also some of the rich green quartzose gneiss found on the south side of the Nimchary hills south of Bellary.

Geology of the Upper Dehing *basin in the* Singpho Hills, *by* TOM D. LA TOUCHE, B.A., *Geological Survey of India.* (With a map.)

The portion of the Singpho hills surveyed by the expedition under Colonel Woodthorpe, R E, during the season 1884-85, includes the whole basin of the Dehing river, which enters the plains at the village of Bishi about 60 miles S.-E. of Sadiya. The nearest area to this valley that had been geologically examined previously was the Makum coal-field, about 45 miles to the west of Bishi, which was described and mapped by Mr. Mallet in 1875.[1] The rocks there were found to be of tertiary age, and were divided by Mr Mallet into four principal groups, called respectively, in descending order, Dehing, Tipam, Coal Measures, and Disang. They dip, as a rule, in towards the main axis of the hills, and are traversed by a great fault, running parallel with the base of the hills, with an upthrow to the south, whereby the Disang group has been brought into contact with the Tipam group, and the coal measures have been brought to the surface. This fault apparently dies out towards the east, as though I found the coal measures on the lower slopes of Miiobúm to the south of Bishi, I could find no traces of the Disang group between the plains and the summit of the Patkoi. The coal measures on Miiobúm were conformably overlaid by rocks which correspond to Mr Mallet's description of the Tipam group, except that they contained none of the fragments of silicified wood which he describes as occurring in the Tipam sandstones.

While the expedition was waiting near Bishi till supplies could be collected for an advance up the valley of the Dehing, I made an excursion, with Mr. Ogle of the Survey, to Maium (6,900 feet), the last high peak of the Patkoi range towards the east. On first entering the hills, in the valley of the Namgoi, I observed blue sandy shales dipping east at about 30°, and some large fragments of coal lying on the shingle in the bed of the stream, but I did not find any of the coal *in situ*. I imagine we must have struck the hills within the boundary of the principal seams, as coal is said to occur in the Namphuk some distance below the junction of the Namgoi. On the lower slopes of Maium similar sandy shales cropped out, striking N-E and S-W, vertical or highly inclined, but between these and the top of the hill I could find no sections. At the summit the rocks were quite horizontal, consisting of thick-bedded yellowish-brown sandstones, in one place containing a seam of coal, 8 inches thick, resting on shale.

[1] Mem. Geol. Surv Ind., vol. xii, pt 2.

These rocks probably represent the Tipam group in the Makum area, but their relation to the highly inclined rocks at the foot of the hill could not be seen. They are probably conformable, the rocks below bending so as to underlie those of the summit. Thus the Patkoi at this extremity is composed entirely of tertiary rocks, like its south-westerly extension the Barail range, in the North Cachar hills.

From Maium the range could be traced for about 30 miles to the E-N-E, but at a much lower elevation, still forming the principal watershed. After which the N-E to S-W, line of disturbance of the Patkoi apparently becomes coincident with that parallel to the Dapha and Phungan ranges. A fine view was also obtained of the Nongyong lake lying close under the ridge to the S-E, and surrounded by a large tract of level grass or reed-covered ground stretching far to the south.

On Maïobûm the rocks were on the whole similar to those on Maium, with a general easterly dip; but here the lower portion contained two seams of coal. Of these, the lower one lies at an elevation of about 1,300 feet above the Dehing and about $1\frac{1}{2}$ miles from it: 3 feet of coal is seen dipping to S-E, at 20°, resting on soft clayey shale. The upper seam is 500 feet higher up the hill, and here 6 feet of coal are exposed, but the seam is probably a good deal thicker, as fragments of coal occur in the jungle for some distance above the outcrop. The coal in both seams is hard with a bright fracture. Close to the outcrop of the lower seam is a small pool in which bubbles of inflammable gas are constantly rising, and several *pûngs*, or springs, much resorted to by wild elephants occur between the two seams. Further up towards the top of the hill the rock, which is exposed here and there, is a generally coarse thick-bedded sandstone, sometimes conglomeritic, and occasionally false-bedded, dipping to E, at from 30 to 40 degrees. At Bishi, on the Dehing, similar sandstones occur forming cliffs about 300 feet high, extending along the right bank of the river for about half a mile. These dip to N-E, at 54°. Between this and the Dapha river, about 20 miles further east, no rock *in situ* was met with, the country being generally covered with drift.

While crossing the Nchongbûm, between the Dungan stream and the Dapha, we camped close to the hot spring mentioned by Mr. S. E. Peal.[1] The temperature of the spring was 89° F. (air temperature 60° F.) and height above sea-level about 2,200 feet. I found that very little water was thrown out by the spring, though Mr. Peal says that about 50 gallons per minute rise, and at first sight it appears as though a large amount were coming up, as it rises in a jet some 8 inches high. This, as I found by the application of a light, is caused by the evolution of a considerable quantity of gas, which took fire and burnt with a flame some 3 or 4 feet high, giving out an odour of burnt petroleum.

At the mouth of the Dapha, and for some distance up the Dehing, thick-bedded sandstones with an E-S-E to W-N-W strike occur, dipping at about 45° to S-S.-W., and resting on blue clays which are exposed at the foot of the terrace on the east bank of the Dapha. About 7 miles up the Dehing cliffs of blue sandy clay are exposed on the north bank striking N.-E., the strike bending round to E, about a mile further on, and the dip varying from 50 to 30 degrees, to N. These

[1] Jour. As. Soc. Beng., vol. lii, pt. 2, p. 46.

beds contain numerous lenticular masses of fine-grained very soft brown sandstones and occasional bands of coaly shale, in one place about 3 feet thick. This is the coal mentioned by Wilcox in his account of his expedition to the Irawadi in 1828[1]; it is an impure lignite. Beyond this the general strike of the rocks is W-N-W to E-S-E, the river flowing along the strike. Sandstones, generally coarse and soft, but sometimes hard and fine-grained, are the prevailing rocks, containing many strings and bands of pebbles, with many fragments of lignite and occasional beds of blue and red shales. They are usually vertical or dip at high angles.

At one place, about 7 miles below Kumki,[2] I observed two very large masses of gneiss extending nearly across the bed of the river, and apparently *in situ*. On the eastern side of them the strike of the sandstones was reversed to N-E for a short distance. If this gneiss is really *in situ* it is the only instance of crystalline rock that I met with in the whole valley of the Dehing. It is a strongly foliated hornblendic gneiss, some portions of it containing garnets. Beyond this the rocks resume their E-S-E strike as far as the village of Kumki. This village is situated in a level alluvial plain about 2 miles long by 1 broad, which must during the rains be almost covered with water. It has been formed apparently by the action of a small stream, the Takhut Kha, which joins the Dehing from the south.

While at Kumki an excursion was made to Biaobúm, a point about 7,000 feet above sea-level, on a ridge about 10 miles to the south. The rocks, wherever sections could be obtained, were sandstones striking E. and W. On Biaobúm they formed scarps from 200 to 300 feet high, with precipitous faces towards the south, running diagonally from N-W to S-E across the general direction of the ridge. From Biaobúm a view was obtained down the Thurong Kong valley to the south. The hills, from the scarped appearance of their summits, were apparently formed of similar sandstones, and were covered with dense jungle. Due south, on the other side of the Thurong Kong, was a range of snow-covered hills with exceedingly jagged summits, probably crystalline, running N-E to S-W.

Beyond Kumki sandstones continue for about 4 miles up the Dehing, when the valley opens out again into a level 'patár,' about 7 or 8 miles long and from 2 to 3 broad. This is entirely covered by drift, but in one or two places patches of blue clay were exposed. This rock, being softer and more easily eroded than the sandstones, would account for the excavation of this large open plain. Beyond this the valley again closes in and sandstones continue, with a general east and west strike, but very variable, to the foot of the hills leading up to the pass over the watershed between the Dehing and the Irawadi. On these hills numerous angular fragments of schistose quartzite were found, but I could find no sections. Further on, about a mile below the top of the pass, fine-grained fissile slates were exposed, striking N-N-W, and dipping to W-S-W at 50°. This rock, with coarser hard gritty bands, continued up to and beyond the summit of the pass, a section near the top giving the strike W-by-N, and another beyond it, east and west, with a dip of 45° to north. The highest portions of the range above the pass are apparently formed of gneiss, as the torrents bring down boulders and pebbles of it from above.

[1] Asiatic Researches, vol. xvii, pp. 322, &c.

[2] Kunk (by mistake) on map.

It will thus be seen that the whole of the valley of the Dehing, and probably a large extent of country to the south of it, are formed of rocks corresponding exactly to the higher tertiary beds of Assam, and altogether of a Sub-Himalayan type. Throughout the valley (with the exception of the doubtful outcrop of gneiss below Kumki) no older rocks whatever occur, and the band of 'axials' and cretaceous rocks, which extends in this direction from Arakan, and was found by Mr. Oldham[1] in the east of Manipur, converging on the Barail and Patkoi, has been entirely buried beneath the tertiaries. In the area described by Mr. Oldham, he found that upper tertiary rocks encroached more and more on the older rocks as they extended northwards, and my observations show that this feature has become completed still further north.

I was unable to examine any of the higher hills to the north of the Dehing, where it is possible that representatives of the Arakan rocks might be found between the tertiaries and the gneiss of the highest peaks; and indeed it appears likely that such would be the case, as large numbers of blocks of serpentine are brought down by the Dehing. This rock is intrusive in the 'axials' of Arakan, and was found well developed in Manipur, forming a dyke running north. Since I found none of it *in situ* at the head of the Dehing, it must be brought down from the higher hills to the north of the river. As to the age of the slates and quartzites at the head of the Dehing, I can form no opinion, as no fossils were found in them, and no sections showing their relation to the tertiaries. Nor did I find any fossils whatever in the tertiaries.

The most striking feature in the valley of the Dehing are the numerous terraces of drift, which are seen in many places at various elevations above the present level of the river. They are entirely composed of very coarse drift with well-rounded boulders both of sandstones from the tertiaries, and of crystalline rocks, principally gneiss. They are most conspicuous on the east bank of the Dapha; and Mr. Peal, in his account of his journey up to the Dapha, gives an admirable sketch of the lowest terrace overhanging the river. This terrace is 250 feet high, and above it are two others equally well defined, the second one 160 and the third 140 feet high. From the top of the third terrace the ground stretches away perfectly level for a considerable distance. On the western side of the Dapha terraces may be traced, though they are not so well defined as those on the eastern side. One occurs at about 160 feet above the valley, and another at 500 feet, while the edge of the topmost plateau is 1,000 feet above the Dapha, and from it the ground slopes gradually up towards the north. On both sides of the Dungan is a well-defined terrace, about 60 feet above the river, which extends down to and along both sides of the Dehing as far as Bishi, forming perpendicular cliffs wherever the river washes against the foot of it. Some patches of drift also occur at Bishi, resting on the sandstone cliffs above the village, at an elevation of 300 feet above the river. Above the mouth of the Dapha the Dehing valley is much narrowed, but drift at a higher level than that reached by the present floods occurs at many places along the banks; and at one spot, about 12 miles below Kumki, is a mass of drift forming a cliff about 300 feet above the river. A large portion of this has formerly slipped down and dammed up the river, forming a

[1] Mem. Geol. Surv. Ind., vol. xix, pt. 4.

lake about a mile long, the surface of which was about 20 feet higher than the present level of the river, as is shown by the numerous trunks of dead trees, killed by the rise of the water, which are still to be seen standing on the banks. The river has cut down through the barrier, so as to have nearly returned to its original level; but there is still a long reach of still water above the barrier, with beds of fine gravel and sand deposited while the lake was in existence.

On the sides of the broad valley at Kumki no traces of terraces could be seen, but the plain about 8 miles higher up the river is traversed by a very well-marked triple one running from N-E to S-W, the lowest step being 20, the second 50, and the third 200 feet above the river.

These terraces must, I think, be due to subsidence in the Brahmaputra valley, allowing the Dehing water to run off at lower and lower levels. The same effect might have been caused by elevation of the upper part of the valley, but in that case it would be difficult to account for the absence of disturbance of the terraces, which are all as horizontal now as when they were deposited. Moreover, we know that subsidence has taken place within recent times in the lower portion of the Brahmaputra valley. The change of level has been considerable, certainly over 1,000 feet, as the beds of drift on the plateau west of the Dapha show.

At first sight the triple form of some of the terraces, as to the east of the Dapha and in the plain beyond Kumki, would appear to show that the change of level had not been a continuous movement, but had taken place by leaps and bounds as it were; but I think that this feature may be accounted for in another way, *viz.*, that during an oscillation of the river from one side of its valley to the other, the alluvium it had deposited on one side would be found on the return of the river to that side to be higher than the present level of the river. These terraces, whose height above each other would depend partly on the rate of change of level, and partly on the length of time taken by an oscillation of the river from one side of the valley to the other and back again, would be formed on either bank. This would also account for the irregularity in the heights of the terraces on opposite sides of the river.

I have noticed similar terraces of drift among the hills both to the north and south of the Brahmaputra, though nowhere so well defined as on the Dehing. They occur in the Digu at the foot of the Aka hills, and opposite the mouth of the Borholi is a large mass of drift, rising to 1,000 feet above the plain, which may be due to the same cause. Terraces also occur in the valley of the Diyung in the North Cachar hills to the south of the Brahmaputra.

On the microscopic characters *of some* Eruptive Rocks *from the Central* Himalayas, *by* COLONEL C. A. McMAHON, F.G.S.

Peridotites.

No. 94–215.—From the *Puga valley.*—LADAK.

This specimen was collected by the late Dr. Stoliczka, who gave the following account of the eruptive rocks met with on the Puga river.

"At first coming to the camp on the Puga stream we met with an epidote rock,

consisting of *epidote, quartz,* and *albite.* The epidote, when crystallized, occurs in short prisms of yellowish or bright green colour. It is often replaced by *diallage* occurring in the same manner in short laminar prisms, and forming a beautiful *syenite-like* rock. Somewhat further to the north the epidote disappears altogether, and the *diallage* is often found disseminated through a dark green serpentine mass, and in this way forming a very peculiar rock, which by many geologists, especially in the Apennines and Southern Alps, would be called *gabbro;* the Himalayan agrees exactly with the Alpine rock. *Diallage* occurs besides in large lumps, and very seldom is any *bronzite* to be seen here. The serpentine rock contains also sometimes sparingly zeolitic and felspathic minerals, and varies greatly in colour. Further to the east, it is occasionally to be found as serpentine-schist and purer in thin veins. In the Puga valley itself no stratification whatever is perceptible in the whole series of these last-mentioned rocks; they have a truly massive structure.

"What is still remarkable, and perhaps worthy of notice, are large spheroidal masses of quartz, which, in addition to numerous quartz veins, occur throughout the serpentine rock.[1]"

The hand specimen examined by me appears to have been taken from the outcrop of the "massive" rocks on the Puga river, in which "no stratification whatever is perceptible." The rock, judged by the sample, is a peculiarly interesting one to me, as it is the first Indian specimen of the ultra-basic class of eruptive rocks that I have seen.

I have examined three thin slices taken from two different sides of the hand specimen at right angles to each other, and all three slices present the same characteristics. The sample consists of a holocrystalline mixture of olivine, augite, enstatite, picotite, and serpentine. It is a variety of peridotite, known as lherzolite, partially changed into serpentine.

In some places the change is complete, patches here and there consisting entirely of serpentine. In other places the progress of conversion has been very partial; for, though the enstatite and olivine are traversed by more or less numerous veins of serpentine, considerable portions of these minerals have escaped serpentinization and remain fresh and unaltered.

Olivine is abundant, and the major part of the rock, prior to the formation of serpentine, was evidently composed of this mineral. As usual in this class of rock the olivine has yielded to the hydrating process more readily than the other constituent minerals, and it is cut up into countless grains divided by a mesh-like arrangement of canals filled with serpentine; the oxide of iron liberated by the decomposition of the olivine being deposited in amorphous masses, principally along the edges, or immediately adjoining the canals of serpentine.

The enstatite is quite colourless in thin slices, but it presents a characteristic foliated appearance under crossed nicols.

The augite is also quite colourless. With ordinary powers none of the minerals present the appearance of "schillerization";[2] but on applying high powers the first trace of this process is observable in the augite, and irregular shaped

[1] Mem. Geol. Surv., Ind., v, pp. 128, 129.
[2] Judd: Quar. Jour. Geol. Soc. xli, 383.

lacunæ are numerous, in which opaque matter has been deposited without completely filling the cavities

The slices under description do not contain any diallage; but, here and there, the first stage of the alteration of augite into diallage may be observed, the characteristic cleavage of the latter mineral having been established. These augites, however, are in other respects quite fresh and give no indication of schillerization

Although neither this sample, nor the next to be described, contain any typical diallage, or felspar, and consequently cannot be called gabbros; still these minerals may be developed in other portions of the rock, and it may locally pass into gabbro Professor Judd in his recent papers has told us how commonly gabbros pass into peridotites in the Western Isles of Scotland.[1] If gabbro is associated with the peridotites of Ladak, however, it is curious that Dr Stoliczka's specimens from both the Puga and Markha valleys should contain no trace of felspar It is to be hoped that future observers in the field will study these interesting rocks more exhaustively and bring back a complete suite of specimens

The specific gravity of the sample, above described, is lower than might have been expected, being 2 85, but this is evidently owing to the loss of iron and the hydration of the olivine, consequent on its partial conversion into serpentine; the specific gravity of olivine ranging from 3 33 to 3 5, whilst that of serpentine is as low as 2 5 to 2 65.

No 94-213 —From the *Markha River, Ladak.*

Dr. Stoliczka, who collected this specimen, refers to the rocks in this locality as follows·

"Already when observing rocks in the Indus valley, north of Gya, I have been very much struck with their more recent aspect as compared with the same rocks (which undoubtedly they are) at the mouth of the Puga stream, examined during my survey of 1864 North of Gya they consisted of soft and partly loose conglomerate, reddish and purple slates and marls, and greenish sandstones, very much like those on the Dugshai hill and to the north of that station. I can attribute this comparatively recent aspect of the rocks north of Gya solely to the subordinate development of the gabbro or diallage rock, which in the Puga valley seems to have perfectly altered and metamorphosed the slates and sandstones."[2]

Dr. Stoliczka proceeds to detail the finding of nummulitic fossils[3] in the sandstones a little to the north of the Markha river, between Rumbag (Rambák) and Skiu, and I gather from his description that the peridotites of the Puga and Markha valleys are intrusive in sedimentary rocks of lower tertiary age. Mr. Lydekker, in his recent memoir on Kashmir,[4] has also mapped the rocks at the mouth of the Puga river, and those a little to the north of the Markha river, as belonging to the eocene period.

[1] Quar. Jour Geol. Soc, xli, 358

[2] Mem. Geol Surv., Ind, v, 343.

[3] *Ib*, p 344.

[4] Mem Geol Surv, Ind, xxii, 107

The sample of the intrusive rock from the Markha valley, when examined with the aid of the microscope, is seen to belong to the same class as that last described. It is almost quite unaltered, however; its serpentinization having proceeded no further than the riddling of the olivine with countless minute canals which form a complete net-work over the whole of it. Olivine is by far the most abundant mineral; enstatite comes next, and augite is somewhat subordinate. As in the last specimen, all these minerals are quite colourless in thin slices. Picotite is present, but is not abundant. The specific gravity of the hand specimen is 3·10.

Volcanic Ash.

No. 94-218.—From *Wangat, Ladak.*

This specimen was collected by Mr. Lydekker, but I have not been able to trace in his published papers any reference to the outcrop from which it was taken.

There is often great difficulty in discriminating between altered volcanic ash and felsites, by their microscopic characters only; but, unless appearances are extraordinarily deceptive, I do not think there can be any doubt as to the nature of this specimen. Under the microscope it is seen to be made up of fragments consolidated by pressure. It contains rounded and sub-angular fragments of quartz; rounded grains of magnetite and ilmenite; and rounded and sub-angular fragments of more or less decomposed igneous rocks, which differ from each other, in some cases, in colour and appearance. The interstices between larger grains are filled up with finer fragments of the same materials.

If further evidence of the nature of the rock was wanting, I think it is supplied by the fact that all the larger fragments are surrounded by a thin margin of an opaque white product of decomposition, and that the grains of magnetite, though more or less converted into the red oxide of iron, appear to have been altered prior to their consolidation in the rock in which they are now found, for the matrix is not streaked with the red oxide, which probably would have been the case had the alteration of the magnetite been due to aqueous agencies operating *in situ.*

The ilmenite exhibits very distinctly its characteristic rhombic cleavage lines. These may sometimes be seen on the surface of the mineral when examined in reflected light, and at other times they are indicated by translucent lines when viewed with the aid of transmitted light. The ilmenite includes very numerous crystals of apatite.

The fragmentary origin of the rock can, I think, be made out by the examination of the weathered surface of the hand specimen with a good pocket lens.

Diorites.

Nos. 96-4, 96-5—Intrusive in nummulitic strata north of *Sirkia.*—HUNDES.

These specimens were collected by Mr. Griesbach. No account of the outcrop from which they were taken has yet been published.

No. 96-4 is a highly altered diorite. The original constituents present in the rock are triclinic felspar and hornblende; and the secondary products of decomposition, calcite, magnetite, a zeolite, and chlorite.

Sphene is present as an accessory mineral. The structure of the rock is granitic.

The felspar is highly corroded, but the characteristic twining of triclinic felspar is still visible in nearly all of it. It is in rather massive pieces, which show no external crystallographic faces: lath-shaped prisms are not present. The angle of extinction of the felspar twins indicates that the species is oligoclase. Hornblende is abundant.

Calcite is present in veins, and also invades the substance of the rock. The calcite veins are peculiarly interesting, as they contain not only air or gas inclusions, but very numerous liquid cavities with active bubbles. The calcite is undoubtedly a secondary product, and the presence in it of liquid cavities with moving bubbles shows that these interesting objects may, in some cases, be due to the operations which gave birth to secondary minerals in a rock long after its consolidation In previous papers [1] I have already noted the presence of liquid cavities with moving bubbles in epidote (a secondary product), and in secondary quartz in the amygdules of altered basalts, and explained their presence by the supposition that the rocks and amygdaloidal cavities were filled, after the consolidation of these lavas, "with the aid of highly heated water or steam under pressure." Mr. G F. Baker, in his memoir on the geology of the Comstock lode (page 371), thought, when he wrote his memoir, that primary and secondary fluid cavities could be discriminated by their shapes, the former being either in the form of negative crystals, or of vesicles, the outlines of which present "smooth curves"; whilst secondary fluid cavities "are bounded by jagged lines." But Professor Judd has since shown that negative crystals [2] with liquid, or other inclusions, may result from "schillerization" and may assume the most regular forms; and I note in passing that the majority of the liquid cavities in the calcite of the rock under description are bounded either by straight lines or "smooth curves." The shape of a fluid cavity, therefore, does not seem to afford a safe criterion for deciding whether it is of primary or secondary origin. In view of this difficulty, the presence of fluid cavities with moving bubbles cannot, I think, be relied on as an aid to the diagnosis of a rock. They may be of primary or they may be of secondary origin, and it seems impossible to discriminate between the two classes by mere inspection.

No. 96-5—This specimen belongs to the same class as the last (No. 96-4), only its alteration has proceeded much further. A zeolite has taken the place of the calcite; and not only are veins stopped with it, but in a portion of the slice it has invaded the ground-mass and has taken the place of the original minerals.

The whole of the slice exhibits the progress of decomposition in a high degree; but enough remains of the original constituents of the rock to show that it was originally a diorite.

Hornblende appears to have predominated over the felspar. Much of the former mineral exhibits the first stages of conversion into chlorite, and some of it has passed into that mineral. This slice does not contain any sphene.

[1] *Supra*, xv., 161; xvii, 179; xix, 74.

[2] Quar. Jour. Geol. Soc, xli, 384, 385.

Preliminary note on the Mammalia *of the* Karnul Caves, *by* R. LYDEKKER, B.A., F.G.S., &c.

Having received and examined the bones collected by Mr. H. B. Foote in the Karnul caves,[1] I present a preliminary list of the Mammalian genera and species which I have been able to identify. My list differs somewhat from that given by Mr. R. B. Foote,[2] as I have found some forms which he had not recognized, while, on the other hand, I am unable to confirm two or three of his provisional determinations. The majority of the specimens sent to me consisted either of bones of Rodentia and Chiroptera, or of fragments of bones of larger Mammals, the greater number of which did not admit even of generic determination. There were also sent a large number of bones from the surface bed, which were all of extremely recent origin, and need no further notice. The following list comprises the forms found in the deposits below the surface bed, exclusive of certain human remains, some of which are briefly noticed in the sequel :—

PRIMATES—1. Semnopithecus priamus, *Blyth.*
" 2. Cynocephalus (*cf.* anubis, *F Cuv.*)
CARNIVORA—3. Felis tigris (*or* ? leo) *Linn.*
" 4. " ? pardus, *Linn.*
" 5. " chaus, *F. Cuv.*
" 6. " rubiginosa, *Geoffr.*
" 7. Hyæna crocuta (*Erxl*).
" 8. Viverra karnuliensis, *n. sp*
" 9. Herpestes griseus, *Desm.*
" 10. " smithi, *Gray.*
" 11. Ursus, sp.
INSECTIVORA—12 Sorex (*cf.* cærulescens, *Shaw*).
CHIROPTERA—13. Taphozous saccolæmus *Temm.*
" 14 Phyllorhina diadema (*Geoffr*).
RODENTIA—15. Sciurus macrurus, *Harda.*
16 Golunda ellioti, *Gray.*
17. Mus mettardi, *Gray.*
18. " platythrix, *Sykes.*
19. Nesokia kok, *Gray.*
20. " bandicoota, *Bech.*
21. Hystrix hirsutirostris, *Brandt.*
22. Lepus (*cf.* nigricollis, *F. Cuv.*)
UNGULATA—23. Rhinoceros karnuliensis, *n. sp.*
" 24. Equus (? 2 *sp.*).
" 25. Bos[3] or Bubalus.
" 26. Boselaphus tragocamelus (*Pall*).
" 27. Gazella bennetti (*Sykes*).
" 28 Antilope cervicapra (*Linn*).
" 29. Tetraceros quadricornis (*Blain*).

[1] *Supra*, vol. xvii, pp. 200-208 (1884), and xviii, pp. 227-235 (1885).

[2] *Supra*, vol. xviii, pp. 231-232. Some emendations have been on the generic and specific terms employed by Mr. Foote.

[3] Including *Bibos* (*Gavæus*).

UNGULATA—30. Cervus aristotelis, *Cuv.*
" 31. —— axis, *Erxl.*
" 32. Tragulus [*cf.* meminna (*Erxl.*)].
" 33. Sus cristatus, *Wagner.*
EDENTATA—34. Manis gigantea, *Gray.*

In this list the crania on which Nos. 16, 17, 18 are identified are from loose red loam underlying the surface bed in the "Charnel House" cave in which human remains occur,[1] but from other fragmentary specimens it is probable that these species also occur in the underlying beds. The most interesting features in the fauna are the two new species (Nos. 8, 23), and the occurrence of Equus and the three Ethiopian forms Nos. 2, 7, 34.

Of the new species, *Viverra karnuliensis* is founded on a mandibular ramus,[2] showing the carnassial and the alveoli of the premolars; the former is very similar to the corresponding tooth in *V. zibetha* and *V. megaspila*, but the space occupied by the premolars is very much longer than in either of those species, the specimen being quite unlike the mandible of *V. civetta.* As the mandible of the Siwalik *V. bakeri*[3] is unknown, it is almost impossible to say whether the Karnul form is identical with this species, but as this is somewhat improbable, I have provisionally assigned a distinct name to the former.

Rhinoceros karnuliensish[4] is a small bicorn, and brachydont species agreeing very closely in several respects with the pleistocene *R. etruscus* of Europe, but differing somewhat in the structure of the upper cheek-teeth, and in the deeper and more defined channel in the mandibular symphysis, and thereby approaching the African *R. bicornis.* The species differs from *R. deccanensish*[5] by its brachydont character and the absence of the distinct cingulum in the upper premolars.

Of the Ethiopian forms the *Cynocephalus* is indicated by a second lower true molar, indistinguishable from $\overline{m2}$ of *C. anubis;* but probably insufficient for specific determination. Of *Hyæna crocuta* there is a lower carnassial and an upper canine; while *Manis gigantea* is represented by a terminal phalangeal of the manush[6] agreeing almost precisely with the corresponding bone in a skeleton measuring 54 inches in length. Both *Cynocephalus* and *Manis*, as well as hyænas of the crocutine group, occur in the Siwaliks; and the present specimens are of great interest as proving that the intimate generic connection existing between the pliocene fauna of India and the recent Ethiopian fauna had in the late pleistocene (to which period I am disposed to refer the Karnul cave deposits) of India developed in some instances into a specific one, traces of which still remain in the existence of species like *Felis leo*, *F. pardus*, and *Canis aureus* in the two areas at the present day.

The *Equus* I have at present been unable to determine specifically, but some of the molars (as Mr. Foote observes) indicate a small species, which may possibly

[1] *Supra*, vol. xvii, p. 205.

[2] Provisionally identified by Mr. Foote (*supra*, vol. xviii, p. 231) with *V. zibetha.*

[3] Pal. Ind., ser. 10, vol. ii, part xxxiii, fig. 1.

[4] Provisionally identified by Mr. Foote (*supra*, vol. xviii, p. 322) with *R. sondaicus* (*javanicus*).

[5] Pal. Ind., ser. 10, vol. i, pts. i-iii.

[6] Identified by Mr. Foote with *M. pentedactyla.*

be closely allied to the African *E. tæniopus*. The occurrence of a small species of *Ursus* is indicated by the *distal* portion of a humerus; but it would be difficult to say to what species it belonged, the most likely forms being the existing *U. malayanus*, and the pleistocene *U. namadicus* of the Narbada valley. Some of the teeth referred to *Sus cristatus* indicate individuals of larger size than the existing race, but I cannot regard this as a specific difference. There are also some slight differences between the upper molars referred to *Cervus aristotelis*, and the corresponding teeth of recent examples, but these may probably be also considered as but racial variation.

Besides the forms I have recorded, Mr. Foote mentions (1) *Macacus* (?), (2) *Canis*, (3) *Paradoxurus* (?), (4) *Tupaia* (?), (5) *Cervulus aureus* (?), (6) *Ovis* (?) and (7) *Capra* (?). Of Nos. 1 and 5 I can find no evidence, while I believe that the specimen on which No. 2 was determined belongs to *Felis*. Of Nos. 3 and 4 the specimens are insufficient for generic determination Some limb-bones from the 'Purgatory' cave undoubtedly belong either to *Ovis* or *Capra*, but as they are of extremely recent appearance, and agree precisely with other specimens from the surface-bed of the 'Charnel House,' I am inclined to think that they cannot be referred to the pleistocene fauna.

With regard to human remains, Mr. Foote records[1] a molar from a depth of 4 feet in the 'Chapter House' cave, which was the lowest level at which such remains were found; and he also records[2] the occurrence of cut bones and implements, but without particularizing the horizons whence they were obtained. As the latter specimens were not forwarded to me, I can of course say nothing about them, but I may observe that a very considerable number of the larger bones sent to me have been gnawed by porcupines, and I would venture to suggest the necessity of submitting the reputed cut bones (and perhaps some of the 'instruments') to a stringent examination with a view of determining whether they may not have been subject to the same action.

The more interesting of the above-mentioned specimens will be figured in a fasciculus of the 'Palæontologia Indica', which I hope to bring out during the current year.

HARPENDEN,
The 8th March 1886.

Memorandum on the prospects of finding coal *in* Western Rajputana, *by* R. D. OLDHAM, A.R.S.M., *Deputy Superintendent, Geological Survey of India.*

As this subject is one of general interest and importance, in view of the great expense incurred for fuel on all the railway lines in North-Western India, and as the discovery of workable coal in this region would allow of the profitable construction of a line of railway much needed on other grounds, I have thought it advisable to draw up a special memorandum, in addition to the purely technical report of my last season's exploration of the desert, showing the evidence at present available on this subject.

[1] *Supra*, vol. xviii, p. 231.
[2] *Ib.*, p. 232.

2. When Mr. Blanford made his traverse from Jodhpur to Rohri in 1876, he noticed the occurrence near Pokran of certain beds, which by the peculiarity of their structure are shown to have been deposited through the agency of floating ice. Mr. Blanford considered that these beds were of Vindhyan age, for, near Pokran, they are overlaid by red sandstones, which closely resemble those seen near Jodhpur. Further west, near Jessalmir, he described the occurrence of marine limestones of jurassic age underlaid by sandstones, whose resemblance to the Mahadeva beds (upper-Gondwanas) of the Indian Peninsula he recognised and commented on; but he did not recognise either the actual or the probable presence of the lower-Gondwana (coal-bearing) series in this district.

3. During the cold weather of 1885-86, I was despatched to explore the great tract of country lying north of Mr. Blanford's route, of which nothing was known except that there were extensive exposures of rock. My route lay from Ajmere through Nagore, Falodi, and Pokran to Jessalmir, whence, after making a loop east into the rocky oasis lying north and north-west of Jessalmir, I returned through Lathi, Bap, and Bikanir to Ajmere.

4. All the country east of Pokran and Bap appears to consist of rocks of Vindhyan age overlaid for the most part by alluvium and blown sand. These rocks are all very much older than those in which our Indian coal is found, and there is no possibility of the occurrence of coal in this region. But along a zone running about north-north-east and south-south-west and extending from Shekasar to Nokra (both villages near the eastern boundary of Jessalmir) there is an exposure of a very characteristic rock.

5. This is almost certainly of the same age as the peculiar glacial beds near Pokran, referred to in section 2, and consists of a matrix of fine-grained marl through which fragments of felsite, syenite, limestone, gneiss, and granite of all sizes from a few inches to in one case over 10 feet across, are scattered; and many of these are smoothed and striated in the peculiar manner characteristic of glacier work.

6. As I have said, there can be no doubt that these are of the same age as the Pokran boulder beds, but fortunately there can be no question here as to their not being of Vindhyan age, for they contain fragments of Vindhyan limestone which must have been indurated and metamorphosed when they were deposited in their present position. It is consequently clear that these beds are of very much newer origin than the Vindhyans, and consequently cannot but be representative of the Talchir boulder beds, the beds *which everywhere in India underlie the coal-measures.*

7. To the westwards of these beds and lying between them and the marine jurassic limestones of Jessalmir comes a series of sandstones, very ill-exposed, but all having a slight dip to west-north-west.

8. We have then recognised, *first*, beds older than the coal-measures; *second*, beds newer than the coal-measures; and *third*, a series of sandstones lying between them: the question arises whether it is probable that coal will be found in these intermediate beds.

9. Before proceeding I must remark that the country under consideration is extremely unfavourable for geological investigation. Undoubtedly actual outcrops of rock are as frequent as is usual in the Indian coal-fields, but on the

other hand the latter are usually intersected by streams in which the rocks are fairly well seen, and it has nearly always been possible by fossil evidence to declare the actual existence or absence of the "Damudas," the group of beds which has yielded all our Indian coal. But in Jessalmir, if we except the western district in which the beds are demonstrably newer than the coal-measures, there is not a single stream bed or even a satisfactory exposure of rock. For the most part the country is a gently undulating plain covered with a sandy alluvium in which there are scattered frequent outcrops of very decomposed sandstone which do not rise appreciably above the general surface and are always so decomposed that it would be hopeless work to attempt a search for fossils, or still more so, for an actual outcrop of coal. Under these circumstances I find it impossible to give a definite opinion as to the presence or absence of this mineral, and can do no more than explain the conditions and possibilities of the case

10. The facts that the beds both above and below the coal-measures are present, and that there is a great thickness of sandstones (certainly not much less than 2,000 feet and probably nearer 6,000 or more) lying between them, indicate the probable presence of beds of the same age as the Indian coal-measures, and, to judge from the fact that we have never yet found beds of the right age without also finding coal, the probable existence of this mineral.

11. There are, however, two possibilities which must be borne in mind, first, that there may be no representative of the Damudas at all; and second, that though beds of Damuda age may be present, but, owing to the conditions under which they were deposited, may not contain coal.

12. As regards the first of these, I have already pointed out that the ground is very unpropitious for geological investigation, and I can consequently give no direct opinion on the subject. On the road from Pokran to Jessalmir there is a stretch of Malani volcanic beds much older than the Talchir boulder bed, and evidently an old land surface in the sea or lake in which the latter were deposited. At the western margin of this old land surface the boulder beds are again seen, and on this section there is not room between them and the exposure of what seem to be upper-Gondwana sandstones at Lathi for the intercalation of any considerable thickness of beds. But to the north of this section, there is a much greater development of the sandstones which at their lower limit appear to pass gradually into the boulder beds, so that it is not improbable that there is here as in the Peninsula a slight unconformity between the lower- and upper-Gondwanas which has allowed of an overlap of the latter on to the Talchir boulder bed.

13. It may of course be that this unconformity in the series—which I may remark in passing is by no means proved but merely indicated by the imperfect observations that alone are possible on a rapid traverse—is universal in this region, but there is so great apparent regularity in the succession of the beds, which lie very flat and with a very regular dip, that I cannot regard this as altogether probable, and consider it more than possible that somewhere in this region, the beds intervening between the Talchirs and the upper-Gondwanas will be found.

14. As regards the possibility of the presence of beds of Damuda age without

coal, this is a more serious consideration. The beds near the top of the series, *viz.*, the Jessalmir limestones, are of indisputably marine origin, and near Bap there are some beds of impure limestone associated with the boulder beds which may be, but by no means necessarily are, of marine origin. Besides this I noticed that at one place some sandstones which appear to underlie the boulder beds had a saline taste; this is not, however, proof of marine origin, as the impregnation with salt may have occurred subsequently to deposition. These facts might be supposed to indicate the probability that the whole series was composed of marine deposits, and if this were the case all hope of finding coal would have to be abandoned.

15. There is, however, some direct evidence pointing to a different conclusion. Between Lathi and Shawal on the road to Jessalmir and again south-east of Jessalmir towards Kita, there are repeated exposures of the sandstones immediately underlying the Jessalmir limestones, whose resemblance to the Mahadevas of the Indian Peninsula has already been noticed (section 2). Now the Mahadevas are acknowledged to be freshwater (river) deposits, and moreover in these sandstones of Jessalmir there are frequent pebbly bands in which the pebbles are not sufficiently numerous to deserve the name of a conglomerate; such beds are common, and easily accounted for in strata of freshwater (riverine) origin, but are not usually found in purely marine sandstones. The beds just referred to overlie a series of sandstones and shales lying between them and the boulder beds which are most probably similarly of freshwater origin.

16. The probability may be therefore considered to be in favour of the freshwater (riverine) origin of any beds of Damuda age which may exist in this region. It does not follow as a necessity from this that they will contain coal, still looking to our invariable success in finding coal wherever we have found beds of the proper age, I cannot regard it as probable that this region will prove an exception to the general rule.

17. I have in the foregoing passages treated the question as impartially as possible, any bias being against a favourable conclusion, but I cannot help regarding the prospects of success as sufficient to justify the expenditure of money on a systematic exploration, especially when we bear in mind the immense value of a workable coal-field in this neighbourhood.

18. My description of the nature of the country contained in section 9 of this memorandum will show that it is impossible in this case to follow the usual course of making certain of the actual existence of rocks of coal-bearing age before recommending the expenditure of money in a search for coal. Here it will only be possible to determine this fact by laying bare the rocks in quarries or sinkings made specially for that purpose, and money devoted to this purpose would be a purely speculative investment in which the prospects of success and failure are about equal, but while it would be impossible to exaggerate the value of success, the cost of failure would be small and limited.

19. As regards the locality most favourably situated for exploration, I would recommend that this be commenced in the country west of the village of Bap. I chose this as, though the boulder beds can be traced both north and south of this, I find that to the north the sandhills lie only a few miles to the west,

while a little north of the village of Bap their eastern boundary bends suddenly round to the west and leaves a much broader area, and consequently greater thickness of rock open for experiment. To the south of Bap the boulder beds die out against the old land surface mentioned in section 12, and it is consequently more probable that a sinking would strike the Vindhyans than further to the north. Moreover, there appears to be west of Bap much more room for the development of a thick series of sandstones, and it is very possible that the Damudas are present here, though cut out on the section between Pokran and Jessalmir by the overlap of the upper-Gondwanas on to the boulder beds.

20. I may add that this country is quite untested by native wells. I was informed that for 20 *kos* west of Bap, there is no well: at Bap itself, I was informed that a well had been sunk to a depth of 50 *purus* (160 feet) without finding water. A well in this position could not possibly strike coal, being started in beds below the coal-measures. In the Gazetteer of Jessalmir, I find a reference (page 169) to a well having been sunk in this region to a depth of nearly 500 feet without finding water. No conclusion can be drawn from there being no mention of coal, for it is not likely that villagers ignorant of the properties or value of that mineral would take any notice even were they to pass through a bed of it in sinking their wells. Nor is the exact position of this well stated.

21. It must not be overlooked that the whole country lying south of the direct road from Jodhpur to Jessalmir is absolutely unknown, and it is by no means impossible that the coal-measures may be present in parts of that region, for the Talchir boulder beds are highly developed at Lowa and Pokran, and may be overlaid to the southwards by newer beds as at Bap. Still in the absence of more detailed examination and with all the reservation necessary on that account, I am inclined to regard the prospects of finding coal in the country west of Bap as being as good as are likely to be met with anywhere else in the region in which alone we may look for it.

22. With regard to the method of the search, either a series of borings might be at once put down in the region I have recommended for trial, or this might first be examined with the help of shallow sinkings, to see whether there would be any possibility of the presence of the Damudas.

23. There can be no doubt that the first would be the most rapid and thorough method, but it would also be the most expensive. It is not impossible that the less expensive form of exploration would show the uselessness of further search but on the other hand if the results so obtained were not absolutely unfavourable, it would be necessary to follow them up by the more thorough method of a series of borings.

24. The country might also be explored by encouraging the villagers to sink wells; this would, however, be very slow, for a well of 300 feet in depth would take quite two years to sink, and would, if we allow a dip of 5° (by no means an exaggerated estimate), only test a thickness of rock corresponding to one mile in width of outcrop.

25. I have not personally seen the country I recommend for trial. In explanation of this, I may say that my instructions were merely to execute a rapid exploration of as large a tract as possible, and that when I reached Bap there was little

or nothing to show me in which direction I would do most good. There were indeed some signs that the dip was veering round to northwards, and in that case a northerly course—the one I adopted—would have proved most profitable. Unfortunately this did not turn out to be the case, and it was only after the completion of my tour and by putting together all the observations I had made, and the information I was able to obtain from the natives of the country, that I formed my conclusions as to the possible existence of coal in the country west of Bap.

26. Under these circumstances I cannot recommend that borings be immediately sunk, but would rather advise the preliminary examination of the district referred to, for which purpose I consider that an establishment of 15 to 20 experienced quarrymen should be sanctioned; these men would be employed in making numerous shallow sinkings and quarries in which the rocks would be laid bare and their nature better seen than in the very bad exposures of decomposed sandstone which are alone visible in this region.

27. On the other hand it is not improbable that the Jessalmir Durbar would be more willing to find money for borings, as these, even if they did not strike coal, would very probably strike water, and it would be impossible to exaggerate the value and importance that is attached to water in this arid region.

A Note on the Olive Group *of the* Salt-range, *by* R. D. OLDHAM, A.R.S.M., *Deputy Superintendent, Geological Survey of India.*

The last number of these Records contained a paper by Dr. Waagen on some palæozoic fossils recently collected from the Olive group of the Salt-range. Dr. Waagen declared his conviction, founded on information supplied by Dr. Warth, that these fossils were derived from concretionary nodules and gave a true indication of the age of the beds from which they were obtained. On the strength of this conclusion Dr. Waagen declared that it would be necessary to divide the Olive series into two portions, one of which was to be regarded as of lower carboniferous, the other of eocene age. I was consequently despatched to the Salt-range to verify on the ground an opinion involving so great a change; the results of my observations, which entirely confirm Mr. Wynne's original mapping, are embodied in the following passages.

On meeting Dr. Warth I was surprised to find that he by no means shared Dr. Waagen's confidence in the concretionary nature of the fragments which had yielded these fossils, and that, though he was not unwilling to allow that this opinion might be correct, and that the fossils truly indicated the age of the bed from which they were obtained, he decidedly inclined to his original idea that they were transported pebbles; on examining the exposures I was able to convince myself that in this he was perfectly correct.

In the first place the bed in which they occur is a thin band of gravel, the last rock in which one would *à priori* expect concretionary nodules to be formed. Then on examining the so-called concretions I found that in many cases the fossils extended right to the surface, and were there abruptly, often obliquely, truncated, not infrequently they could be seen exposed in section on the abraded surface of the pebble and occasionally fragments could be found showing on their surface

the abraded and more or less obscured impressions of *Conularia* or of one of the associated bivalves.

This would in itself be sufficient proof, but confirmatory evidence is not wanting. There are associated with this bed some shaly bands lithologically very similar to the matrix of the *Conularia* pebbles, but these bands have so far yielded no trace of a fossil: further, near Choah Saidan Shah, where the band is less markedly gravelly and where the pebbles have more the appearance of concretionary nodules than near Tobar, there are frequent lenticular masses of an inch or more in thickness and 6 to 12 inches in length which are undoubtedly of concretionary origin and formed *in situ*, but those, though they have been most carefully searched by Dr. Warth, have yielded no trace of a fossil. Yet another piece of evidence is the occurrence, though very rarely, of pieces of pale micaceous sandstone in this band, and one of these fragments showed obscure impressions of *Conularia;* now this fragment was angular in outline, and is moreover very different in aspect from any concretionary nodule that has ever been seen by me—or, I may safely say, any other geologist.

After this it might be thought superfluous to add anything further, but it will at any rate be advisable to notice the arguments on which Dr. Waagen based his final conclusion. Of these, the last, that founded on the homogeneity of the fauna, is without doubt the most important, and when taken in conjunction with the fact that four out of ten species are either identical with or closely allied to species which in Australia are found in beds that also exhibit proofs of glacial action,[1] would seem to make this argument conclusive. Nevertheless, in the face of direct evidence pointing to a different conclusion, this becomes worthless. The peculiarity, however, requires some explanation, and I offer the following hypothesis as one that is at least possible; a careful examination of the fossiliferous pebbles has induced me to believe that for the most part they were originally concretionary nodules, though occurring in their present position as transported pebbles. I base this conclusion on the fact that they are frequently of somewhat irregular shape, and that then it is usual to find the fossils completely imbedded, while those pebbles which show distinct traces of transportation and in which the fossils are truncated at the surface are usually fairly well rounded and water-worn. It will be seen that if this contention is correct, and if shaly beds with concretionary nodules, for the most part formed round fossils, had been exposed in the neighbourhood, it would not be difficult to account for the abundance of pebbles formed from these same nodules.

With regard to Dr. Waagen's first reason, the restriction of the "concretions" to the top of the bed in which they are found, I cannot allow this to pass as a correct description of their mode of occurrence, though, if correct, I do not consider that it would prove anything. Undoubtedly the fossiliferous pebbles do occur more abundantly near the top of the bed than in the lower portions; but this is easily explained by the fact that most of the pebbles in this band of gravel are of quartz or hard crystalline rock, and are of greater specific gravity than the fossiliferous pebbles. In consequence of this, the latter would be swept away by a current only sufficient to transport the former; but as the current died away, it would no longer

[1] *Supra*, p. 44.

bring down the heavier pebbles and a layer of the lighter fossiliferous pebbles would be deposited before the current ceased to be able to transport even them. This hypothesis is supported by the fact that, while the crystalline pebble gravel is very distinct near Tobar and Pid, it is almost absent in the exposures near Choah Saidan Shah, and the bed, here very much thinner, contains very few pebbles besides the fossiliferous ones and some of slate and impure limestone.

This thinning out of the bed to the northwards is in contradiction to Dr. Waagen's original supposition, that the fossils came from the Himalayas—an opinion which must have been founded on pure hypothesis, and is not supported by any known fact for, not only have no Himalayan beds yielded fossils similar to those of the pebbles, but all the fragments of rock in the associated boulder beds are of most conspicuously peninsular origin, not a few are of the very peculiar and easily recognizable Malani porphyry. It is consequently to the southwards that we must look for the original source of these fossils; the only locality where any rock is exposed in that direction is the Korana hills, and unless the mother rock of these pebbles is found there or in the Salt-range itself, it must be buried beneath the alluvium of the Punjab.

Having shewn that the fossils are of derivative origin and can, consequently, not be appealed to in determining the age of the beds in which they occur, it remains to see whether there is any stratigraphical evidence in favour of the association of the boulder beds of the Olive group with those of the speckled-sandstone which has been advocated by Dr. Waagen, and to determine whether it will be necessary to draw any line of division in what has so far been regarded as a single group. I may at once remark that I can find no evidence whatever in favour of these hypotheses, but have every reason to agree with Mr. Wynne in associating these beds with the nummulitics rather than with the older beds, and in regarding them as forming a single homogeneous series.

Not the least forcible of these is the fact that Mr. Wynne, a most careful observer, the accuracy of whose mapping it would be impossible to overpraise, and who had most ample opportunities for examining the rocks in detail, was distinctly of opinion that the beds of the Olive group belong to a single conformable series of beds, and that this is more closely related to the overlying nummulitic beds than to the underlying salt-pseudomorph group which he regarded as of triassic age.

That this conclusion is correct, is proved by the marked unconformity which can be traced between the salt-pseudomorph group and the Olive group, and the equally marked gradual transition from the latter into the soft white sandstones which underlie the nummulitic coal.

This unconformity is well seen on the main road from Pind Dadan Khan to Rawalpindi just beyond the 8th milestone, where the road runs in a sidelong cutting in the steeply sloping hill side. Here there may be seen a small lenticular patch of boulder conglomerate apparently interbedded in the red beds of the salt-pseudomorph zone, but this is so exceptional and so much at variance with what is seen elsewhere that I cannot doubt that the interbedding is only apparent and that the appearance is due to slippage, of which there is ample indication just here. But everywhere, as long as the junction is exposed on the road section, the boulder conglomerate is seen to rest on the obliquely and irregularly truncated edges of

the beds of the salt-pseudomorph group. Where the boundary runs up the hill side this is of course not so clearly seen, though the unconformity can be detected in the ravines; but here, as in the road cutting, the boulder bed where in contact with the older rocks is full of fragments evidently derived from them.

An equally cogent argument may be derived from the fact that on all the sections I have examined the base of the Olive group is well marked by the sudden appearance of boulders of crystalline rock of large size. At their first appearance they are always fairly abundant and below the point at which they first appear, not even a pebble can be found *in situ.* But passing upwards the very reverse is the case, the boulders disappear gradually, becoming rarer and rarer, and long after they cease to occur with any regularity isolated fragments may occasionally be seen. Traces of glacial action are not common as high up in the series as the *Conularia* bed, but they do occasionally occur, as near Tobar, and on the descent from the Dandot plateau to the Makrach gorge (where I did not find the *Conularia* bed), one boulder occurred in a white sandstone which appears to represent the *Cardita beaumonti* zone. Now the section up from the *Conularia* bed, which evidently must be associated with the glacial boulder beds, to the soft white sandstone which underlies the coal shale, can be very well seen in several places and nowhere perhaps better than on the western descent from the Pid Bungalow (Pid Pole of the map) and on the hill side just mentioned above the main road close beyond the 8th milestone from Pind Dadan Khan, and wherever the section is well exposed there can be seen to be a continuous sequence and gradual transition from the *Conularia* bed to the soft sandstones which, as far as I can understand the case, represent the *Cardita beaumonti* zone of Dr. Waagen. The section above these cannot be so well seen, but there is no reason whatever for supposing that there is anything like an unconformity between them and the nummulitic coal shales.

Dr. Waagen has suggested that the boulder beds of the Olive group and those of the speckled-sandstone are the same. I find it impossible to accept this view, for not only did Mr. Wynne regard them as absolutely and entirely distinct, but the colouration, from which their name was derived, is so marked and so distinct that it is possible to recognize the occurrence and even to trace the boundary of this group from a distance—in fact from as far as it is possible to see the distinction between hill and valley. It is hardly conceivable that this strongly marked feature should be a merely local phenomenon and not indicate a difference of age.

The stratigraphical relations of the beds are thus seen to show that the Olive group is a homogeneous group and must be associated with the overlying nummulitic beds rather than with the underlying palæozoic or early secondary beds.

If it should be objected that it is improbable that there should be such a development of glacial boulder beds at more than one geological horizon, I would point out that Mr. Lydekker found beds of evidently glacial origin, in Ladak, which, like those of the Salt-range, conformably underlie the nummulitic series.[1]

[1] This must be taken merely as a suggestion. I do not bind myself to anything except that the fossils occur in derivative pebbles, and that the Olive group of Mr. Wynne is of later origin than the rock from which they are derived.

As regards the speculations Dr. Waagen has based on these fossils, they are very similar to some which I put forward in 1884,[1] except that the latter were perhaps more in accordance with the known principles of physical geography, which hardly warrant us in picturing a glacial epoch wandering about the earth like a lion seeking whom or what it may devour. All such speculations, though useful in indicating possibilities, should be used with great caution, and should not under any circumstances be regarded as serious geology.

To sum up: 1st, the fossils discovered by Dr. Warth being of derivative origin, simply prove that the Olive group is post-carboniferous; 2nd, the stratigraphical relations of the beds prove that it is a homogeneous group which is closely associated with beds of acknowledged nummulitic age; 3rd, it is in all probability of contemporaneous origin with the infra-nummulitic glacial beds of Ladak; 4th, there is at present neither need nor reason for a revision of Mr. Wynne's survey; and 5th, the question as to the age of the Talchir group of the Gondwana series is left precisely as it would be had these fossils never been discovered.

Memorandum *on the discussion regarding the* boulder-beds *of the* Salt-range, *by* H. B. MEDLICOTT, *Director of the Geological Survey of India.*

The promulgators of an important announcement are bound to give immediate publicity to any doubt that may arise regarding it, and I accept Mr. Oldham's note as throwing much doubt upon the new view of the Salt-range sections expounded by Dr. Waagen in the last number of the Records; but as the note is not completely demonstrative and exhaustive, it is desirable to anticipate further discussion by an appraisement of the present evidence on both sides.

Having no personal knowledge of the ground, I accepted the new view on its merits as represented by Dr. Waagen, who next to Mr. Wynne was most familiar with the sections in question, and he was moreover in direct communication with the observer who furnished the immediate data for the change of interpretation. In adopting the view so forcibly presented I had the satisfaction of finding that no discredit was imputed to Mr. Wynne's work. Besides that Dr. Waagen was himself almost as much concerned as Mr. Wynne in any oversight that had been made, it seemed that the oversight in question was of a most venial nature—the not having detected fossils in a particular thin bed of gravel; and I know well how deceptive may be an appearance of natural continuous sequence of strata. On the whole, as represented by Dr. Waagen, the proposed view seemed to me to reconcile some apparent anomalies in the stratigraphy of the Salt-range as represented in Mr. Wynne's memoir, notably the similarity noticed by him in the several boulder-beds placed in very different horizons, although apparently in more or less continuous connexion. I even thought that the new reading would be especially pleasing to Mr. Wynne, as tending to re-vindicate his original view of the occurrence of older palæozoic strata in the eastern Salt-range, which had been the principal point of difference between him and Dr. Waagen. I did indeed perceive a want of due discussion of petrological and stratigraphical evidence in

[1] Some rough notes for the construction of a chapter in the History of the Earth, J. A. S. B., (1884).

Dr. Waagen's presentation of the case, but this seemed attributable to the fact that Dr. Warth is not a practised observer, and the main arguments brought forward appeared overwhelming; these were, the occurrence of a small special fauna in a particular bed over a large area; and, that the reputed boulder-bed of the Olive group comes to an end just where the speckled-sandstone boulder group comes in. Coincidences such as these would be little short of miraculous if fortuitous; and the two together seemed, as I say, overwhelming. Nevertheless I determined to have the case looked into at an early date. My only reluctance in deputing Mr. Oldham for this duty was that he might be unconsciously inclined to favour a view that seemed to tally so well with his own recent observations. His decision has, however, been decidedly adverse.

It would have been impossible for Mr. Oldham in a short visit at the end of the working season, when the Salt-range is like a fiery furnace, to have made anything like an exhaustive study of this question. He confirms the leading facts of the occurrence of these peculiar fossils, though not absolutely restricted to the one layer. This of course so far strengthens Dr. Waagen's position, upon the exclusive presence of palæozoic fossils in what were taken to be cretaceous deposits. Mr. Oldham brings the petrological evidence to what he considers demonstration point: that these fossils are all transported and cannot therefore be taken as indicating the age of the bed in which they occur; he admits that the 'pebbles' were originally concretionary, but that in their present position they are true pebbles. It is at least possible to demur to some of his arguments involving '*à priori*' views of what may or may not be possible in this mode of solidification. The symmetry of form usually conveyed by the word 'nodular' is more or less implied in this argument as necessary, which may be questioned: most of us have seen conglomerates and gravels cemented by carbonate of lime in more or less irregular form and degree; kankar and flints commonly assume the most fantastic shapes, and I certainly have seen flints with fossils not merely appearing at the surface but projecting beyond it. Again, these *Conulariæ*, like most fossils, were at first virtually pebbles, and subject to abrasion from water movements; can it be said to be *à priori* impossible that in becoming included in lumps formed in the matrix the abraded end of a *Conularia* might remain at the surface of the lump so formed? Mr. Oldham's ruling on this petrological point might be made almost absolute if he could assert that the ground-mass of the gravel bed is quite different from that of the fossiliferous pebbles in the bed.

But even granting the literal correctness of Mr. Oldham's opinion, that these fossiliferous pebbles were not formed in the very bed where they occur and are not therefore rigorously contemporaneous, the puzzle would not be solved; nor is it much affected by Mr. Oldham's explanation of how these pebbles might have been sorted as we find them. This only shows how the disputed fact must have come about if it is a fact, but to avoid which Dr. Waagen felt compelled to adopt the view he has brought forward. Is it conceivable that in upper cretaceous time, when the abundantly fossiliferous permian and secondary deposits were in force in the neighbourhood and presumably exposed to denudation if older deposits were so, a special collection of fossils from those older deposits can have

been raked together, transported together, and deposited together at a distance by the promiscuous process of detrital agency? Is it not more plausible to suppose that they were washed into the gravel bed from some contemporaneous (palæozoic) pool deposit close by? So long as special palæozoic fossils only are found in these beds, their upper cretaceous age will be open to doubt.

Mr. Oldham next takes up the stratigraphical question of the relation of the *Conularia* beds to those above and below them. As to the upward succession he strongly re-affirms the view of a continuous sequence up to the nummulitic coal-measures. This opinion must carry much weight; but it would be difficult to say that the possibility of deception is inadmissible. Even if a stray *Conularia* pebble were found in the true *Cardita beaumonti* beds there would be no wonder, considering their abundance in the zone below. The strong unconformity of the boulder-bed to the underlying salt-pseudomorph group would only be pertinent to the question at issue through the relation of the latter to the speckled-sandstone group, regarding which point no fresh information is given.

The lines of evidence so far considered are only susceptible of cumulative proof. In the sections west of Makrach it ought to be possible to get absolute evidence in favour of the old interpretation if it be tenable. This is the second crucial point in Dr. Waagen's position, the relation of the eastern boulder-bed to those of the speckled-sandstone. Mr. Oldham's investigation did not reach so far.

Even if the eastern end of the boulder beds should remain as originally placed, in the cretaceo-eocene zone, those of the western and trans-Indus sections which are undoubtedly palæozoic, will still hold the position assigned to them by Dr. Waagen, as presumably representing the Talchirs.

Note on the Gondwana Homotaxis, *by* R. LYDEKKER, *B.A.*, *F.G.S.*

It is extremely interesting to notice how very closely the age assigned to the different groups of the Gondwanas from the discoveries recorded by Dr. Waagen[1] and Mr. Oldham[2] tallies with that indicated by the vertebrates. In dealing with the vertebrates of certain Gondwana groups, I have shown[3] that their evidence taken alone would indicate the following homotaxy, *viz.*:—

Low. Jura.:—Kota }
Up. Trias.:—Maleri. } (Jabalpur and Rajmahal).
Low. Trias.:—Panchet.
Permian:—Bijori, and Mangli (Up. Damuda).

This would indicate that the Barakars (Low. Damuda) correspond either with the lower permian or the upper carboniferous, and the Talchirs either with the upper or lower carboniferous.[4] In the face of the apparently contradictory

[1] 'Rec. Geol. Surv. Ind.,' vol. xix, pp. 22—38 (1886).
[2] *Ibid*, pp. 39—47.
[3] 'Palæontologia Indica,' Ser. 4, vol. i, pt. 4. p. 2, and pt. 5, p. 2.
[4] Dr. Waagen classes the Salt-range boulder-bed (the equivalent of the Talchirs) with the upper carboniferous, as he affiliates it to the lower Productus-limestone which is provisionally referred to the same period. The marked unconformity between the two suggests, however, as Mr. Medlicott observes, a somewhat lower horizon (? lower carboniferous) for the two boulder-beds.

plant-evidence, I did not venture to assert that such homotaxy was the true one, but its almost precise agreement with that given by Dr. Waagen [1] can scarcely be an accidental coincidence, and therefore indicates that it may be approximately accepted, and also shows that in future greater value may be attached in such cases to vertebrate evidence than has hitherto been considered prudent.

The second point I have to notice is the probable occurrence in the North-West Himalaya of a representative of the Salt-range (Talchir) boulder-bed. In the Kashmir area the Kuling series apparently corresponds to the lower Productus-limestone, which Dr. Waagen [2] regards as probably equivalent to the upper carboniferous.[3] Beneath this series there occurs a considerable thickness of trap, underlain by a conglomerate, which has been correlated with the Blaini group of Simla, and has been compared both by Colonel McMahon and myself [4] to a glacial boulder-bed. Disregarding the traps, the presence of which is so-to-speak accidental, it will be apparent that the boulder-bed holds much the same relative position to the Kuling series as the Salt-range boulder-bed does to the Productus-limestone, and the presumption therefore is that the two are approximately equivalent. Other boulder-beds lower down in the Himalayan series point to the prevalence of glacial conditions at an earlier epoch.

ADDITIONS TO THE MUSEUM.

FROM 1ST JANUARY TO 31ST MARCH 1886.

Specimens of sandstone, white marble, ferruginous limestone, and limestone, some cut and polished, and gypsum in the raw state and prepared for use, 21 specimens in all, from different localities in Jodhpur and Jesalmir.

PRESENTED BY THE POLITICAL AGENT, JEYPORE.

Six specimens of bloedite from the Warcha mine, Mayo salt-mines, Punjab.

PRESENTED BY DR. H. WARTH.

Some gem sand (mostly spinel) from Mogout, Upper Burmah, and a specimen of jadeite from the palace, Mandalay.

PRESENTED BY DR. R. ROMANIS, RANGOON.

A specimen of cerussite, with quartz and ochre, from Bardi district, South Rewah.

PRESENTED BY MAJOR D. W. K. BARR, POLITICAL AGENT, BHAGELKHAND, AND SUPERINTENDENT OF REWAH STATE.

[1] *Op. cit.*, pp. 34-35.

[2] *Op. cit.*, p. 32.

[3] Basing my judgment on the number of species common to the Kuling and Productus-limestone and the Mountain-limestone, I have previously (Mem. Geol. Surv. Ind., vol. xxii, p. 161 [1883]) referred both the former groups to the lower carboniferous, having overlooked a previously published note of Dr. Waagen's to the effect that the Productus-limestone was not newer than the upper carboniferous (see Manual of Geology of India, Pt. 2, pp. 492-3 [1879]). The reference of the Kuling to the upper instead of the lower carboniferous accords much better with the fauna of the succeeding strata, which (as in the Salt-range) has a triassic facies. The age of the Moth series (provisionally referred by Stoliczka to the upper silurian) which underlies the Kuling of Spiti, and has been correlated with the Blaini, requires re-consideration.

[4] Mem. Geol. Surv. Ind., vol. xxii, p. 247.

A large piece of nummulitic coal from Chitteedand, 10 miles west of Khewrah, Salt-range, Punjab.

PRESENTED BY DR. H. WARTH.

Four specimens of fossil plants from the Raniganj colliery.

PRESENTED BY MR. G. BARTON, RANIGANJ.

Pebbles with *Conularia*, etc., from the Olive group of the Salt-range.

PRESENTED BY DR. H. WARTH.

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BALL, *Valentine.*—On the collection of the fossil mammalia of Ireland in the Science and Art Museum, Dublin. 4° Pam. Dublin, 1885. THE AUTHOR.

BECKER, *George F.*—A theorem of maximum dissipativity. 8° Pam. New Haven, 1886. THE AUTHOR.

" A new law of Thermo-Chemistry. 8° Pam. New Haven, 1886. THE AUTHOR.

BONNEY, *T. G.*—On the Archæan rocks of Great Britain. 8° Pam. London, 1885. R. LYDEKKER.

" Address delivered at the anniversary meeting of the Geological Society of London on the 20th February 1885. 8° Pam. London, 1885. R. LYDEKKER.

BRONN'S Klassen und Ordnungen des Thier-Reichs. Band VI, Abth. 3, lief. 48-49. 8° Leipzig, 1885.

BUCKLER, *William.*—The larvæ of the British Butterflies and Moths. Edited by H. T. Stainton. Vol. I. (Ray Soc.). 8° London, 1886.

CAMERON, *Peter.*—A monograph of the British Phytophagous Hymenoptera. (Tenthredo, Sirex and Cynips, Linné). Vol. II. (Ray Soc.). 8° London, 1885.

COPE, *E. D.*—Synopsis of the species of Oreodontidæ. 8° Pam. Philadelphia, 1884. R. LYDEKKER.

" On the structure of the skull in the Elasmobranch genus Didymodus. 8° Pam. Philadelphia, 1884. R. LYDEKKER.

DOYLE, *Pat.*—Coal-mining by blasting in the Bengal coal-fields. Flsc. Pam. Roorkee, 1885. THE AUTHOR.

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" Sur les calcaires frasniens d'originne corallienne et sur leur distribution dans le massif paléozoique de la Belgique. 8° Pam. Bruxelles, 1885. THE AUTHOR.

" Note sur le Devonien Inférieur de la Belgique. 8° Pam. Bruxelles, 1885. THE AUTHOR.

FRITSCH, *Dr. Ant.*—Fauna der Gaskohle und der Kalksteine der Permformation Böhmens. Band II, heft 2. 4° Prag, 1885.

GREWINGK, *C.*—Die geognostischen und orographischen verhaeltnisse des Noerdlichen Persiens. 8° St. Petersburg, 1853.

Titles of Books. *Donors.*

JACKSON, *James.*—Tableau de diverses vitesses exprimées en mètres par seconde. 8° Pam. Paris, 1885. THE AUTHOR.

KUNZ, *George F.*—Precious stones. 8° Pam. Washington, 1885. THE AUTHOR.

LEMOINE, *M.* Étude sur le Neoplagiaulax de la faune éocène inférieure des environs de Reims. 8° Pam. Paris, 1883. R. LYDEKKER.

LEMOINE, *Victor.*—La vigne en champagne pendant les temps géologiques. 8° Pam. Chalons, 1884. R. LYDEKKER.

LYDEKKER, *Richard.*—A revision of the antelopes of the Siwaliks. 8° Pam. London, 1885. R. LYDEKKER.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 3.] 1886. [August.

Geological Sketch of the Vizagapatam District, *Madras; by* WILLIAM KING, B.A., D.Sc., *Superintendent, Geological Survey of India.*

INTRODUCTORY.

The regular operations of the Survey have not yet been carried further north along the east coast than the southern limits of the Vizagapatam district; but, while on deputation last September with a view to ascertaining the possibility of artesian boring in Vizianagrum, I had an opportunity, through the facilities so graciously afforded me by His Highness the Maharajah of Vizianagrum and by the Rajah of Bobbili, of examining a good deal of the central and northern portions of the country, the results of which are now given as a preliminary and tentative sketch.[1]

Artesian exploration.—The endeavour to obtain water by an artesian well had indeed been already made, in 1884, to the extent of boring into the crystalline rocks to a depth of 350 feet: the visible result being a well of exceedingly small diameter (6 inches at the most), holding water at some 30 feet below the surface of the ground. The story is simple and suggestive. The papers relating to artesian wells, already contributed to these Records by the Director of the Geological Survey, show the conditions under which subterranean waters having a tendency to rise over the ground surface may be expected to exist; the most promising in India being those of porous strata occurring in extensive alluvial tracts having an increasing landward rise and supposable reception of water at the higher level. A notable exemplification is that of the alluvial deposits of Pondicherry which were tapped successfully some seven years ago: and as a consequence, ever since that time, hopeful looks have been cast at coastal and even inland alluvial plains. There is, however, no alluvial tract worthy of the name at Vizianagrum. Hard gneiss occurs in the immediate neighbourhood

[1] My examination of Vizagapatam itself was also most obligingly facilitated by Rajah G. N. Gajapati Row, whose kindnesses I had already experienced many years before in Madras.

of the town which is also environed by stretches of rising rocky ground or by hillocks and even hills of considerable height of the same class of rock; so that, on the face of it, no rising water could be expected. A mistaken idea has also arisen that the mere presence of hilly ground near or at a distance holds out a prospect of subterranean waters having a head, on which account the Elephant Hill or Chota Himalaya close at hand, or the lofty Galikonda range 30 miles to the west, used to be brought into the argument without any consideration of the fissured or jointed condition, or discontinuous stratification of the crystalline rocks forming them. However, the exigencies of the town as regards water-supply are such, that an artesian well was thought of as the possibly most convenient and even economical way of meeting them. In due time, two Canadian oil-well prospectors turned up, who, after a little concession to the Brahmin augurs, fixed upon a site on the fort glacis, and in time pierced several kinds of highly quartzose gneiss with the result mentioned above. A convenient force pump, called an American Artesian Pump, for raising water at any rate, was also judiciously provided; and as water did not rise, this was brought into play. Concerning its action the following extract from the Canadian Engineer's report is significant:—"Based on a long experience of these pumps, I should say that the stream pumped would yield about 4,000 to 5,000 gallons per diem. The yield would have been increased by running the pumps faster." Mr. T. D. Harris, the Executive Engineer of Vizagapatam, was subsequently deputed to examine the works and from his report it is only necessary here to quote as follows:—"All then being in order, the pump was started at $\frac{1}{4}$ past 4 o'clock and worked to a $\frac{1}{4}$ past 5 o'clock, exactly an hour; during this period there was no hitch or stoppage whatever, but the quantity of water pumped was at the rate of only $\frac{1}{2}$ a cubic foot per minute, or 30 cubic feet per hour, when the well was pumped perfectly dry. The water was sweet and wonderfully discoloured, and particularly the last stuff brought up being a dark bluish mud. The pump I may state was put down to a depth of 344 feet or nearly the bottom of the boring; thus it will be seen that pumping by steam oxen or coolie labour is absolutely out of the question, there being no water to pump."

At first sight, the general question of the artesian capabilities of the district does not appear so absolutely hopeless as this particular one of Vizianagrum; for an examination of the Atlas Sheet No. 108, which displays most of the country, gives the impression that the extensive tract to the north of the Vizianagrum hills is more or less of a great plain largely made up of alluvial tracts belonging to the Chicacole river system, and to a smaller extent of the Konadah river drainage. Even on the ground itself, and to an experienced man well acquainted with the district, the appearance is as of a wide sea of alluvium, out of which the ridges and hill masses rise like so many islands. In reality, however, the low country is rather rugged and rocky, somewhat smoothed down by a thin covering of debris; while there are only very narrow belts of alluvium bordering the rivers. These flatter tracts too are not only very narrow; they are also shallow and crossed at intervals in the bends of the rivers by barriers of rock; and thus, although they have considerable inland length and rise, any porous and water-holding strata occurring in them must frequently be broken in continuity. It is

indeed a peculiarity of the Vizagapatam low country, as compared with the east coast plains of the Madras Presidency to the southward, that it should be so singularly devoid of wide and extensive landward-tailing alluvial stretches.

GEOLOGICAL.

Physical features.—The district is an essentially picturesque one, and in physical aspect it differs a good deal from nearly all the southern portion of the east coast. Up to this parallel, the Coromandel is distinguishable as a broad belt of low land or plain edging the sea, having distant hills and, in the more northern portion, a decided mountain barrier broken only once by the broad valley of the Kistna, as the western back-ground. The hilly barrier bearing the general name of the Eastern Ghâts is, towards Vizagapatam, supplemented by a series of parallel N.E.-S.W. ridges which approach nearer and nearer to the coast; or by outlying ridges and hill groups which at last in the neighbourhood of the town itself assume a more eastward trend running straight at the sea by the group ending in the Dolphin's Nose on the south side or by the much larger whale-back mass of Kailassa to the north.[1] The latter range is continued by its strata in yet more northerly lines along the coast by Bimlipatam, and finally, about the parallel of Konadah, turns inland again into connection with the Elephant Hill or Chota Himalaya group between which and the Vizagapatam hills lies the proper plain of Vizianagrum largely broken up by further systems of ridges, isolated hills, or low reefy hillocks, all running or lying in straight or curved lines having a more or less N.E.-S.W. direction. Northward of the Vizianagrum hills again lies the much more extensive and open country drained by the Chicacole river, still streaked however by scattered hills. At the same time, the distinctive feature of the western main barrier still remains, some 40 miles inland, speciallized by the Galikonda range with its blunt cusps rising up to heights of from 4,000 to over 5,000 feet; the whole forming the highest portion of the step or ghat leading to the wide uplands of the Jeypore and Bastar territories.

The western hill tract is however as yet little known or appreciated either for its scenery or its climate. The structure and beauty of the district are, in fact, best known in the neighbourhood of the three principal towns, or more specially on the coast where indeed it is not to be wondered at that admiration has always been excited. I suppose no more cheering and, to a certain extent, somewhat European prospect could bless the eyes of men wearied with the monotonous and apparently endless streak of low sandy tract with fringing palmyra palms, or pandanus clumps, or the later introduced casuarina plantations, of all the eastern shore from Point Calamere to the Northern Circars, than that of Vizagapatam with its headland and the other hilly surroundings. It is here too that, for the first time, European residents can have their bungalows planted, as at Waltair (Ulteru), on a partially tree-grown rocky ridge whence they can look out over the sea, or watch it tumbling in at the foot of the great headland, from a vantage ground running up to 239 feet over sea-level; or can point to such a pretty indentation as Lawson's Bay and its picturesque environment of hills. In dull and stormy

[1] The name Kailassa was I believe given to this hill by Mr. E. C. G. Thomas, late M. C. S.; it is a part of the Sri Simbashalum temple range.

weather the Vizagapatam coast might be a bit of English sea-bord: at other times with all the glorious colouring of the evening or the morning it might vie with part of the Riviera; the once Dutch town of Bimlipatam with its bright and vari-coloured fort and houses nestling among garden trees at the foot and up the lower slopes of a big flat-topped hill whose deep-red face is scored with brown purple streaks of rocky outcrop, even lending colour to such a passing dream of the Italian coast.

Formations.—When the rocks of a district are so agreeably brought before the eye as is the case here, it is only natural that interest in and some knowledge of them should have been aroused and attained long ago; and as it happens more easily so from the fact that the formations are few and well-marked. The only original work however referring to the geology of the district is that of Dr. Benza, who in 1835 accompanied the then Governor of Madras on a tour through the Northern Circars, and whose diary was subsequently published in the Madras Journal of Literature and Science.[1] Extracts from this diary, and some later information, are also to be found in Mr. Carmichael's admirable Manual of the Vizagapatam district.

The almost universal prevalence of crystalline rocks was indeed to be inferred from Dr. Benza's interesting notes and from what had been learned afterwards in the survey of the Godavery district[2] where the garnetiferous gneisses of Bezvada constitute nearly the whole of the hill ranges there as they are striking due north-eastward into the Northern Circars. It was hardly to be expected on the other hand that the Gondwána rocks of Ellore, &c., or the overlying cretaceo-eocene traps and associated fossiliferous beds, with the succeeding sandstone and laterite of the Rajahmundry neighbourhood, trending as they do gradually towards the sea-coast, where one at least of them ends in the low ridge of Innaparazpolliam, could occur again to the northward beyond the seaward headlands of gneiss in Vizagapatam. Such in fact is the case, and, save these crystalline rocks, there are only such other deposits as are of recent or post-pliocene age, and even of these only very few. Dr. Benza considered indeed that the coastal laterite occurs as a capping to the Bimlipatam hill; but such a particular development is not borne out by the facts of the case, the lateritoid character of portions of the summits of that hill being in reality a result of change or alteration of the weathered or decomposed parts of the garnetiferous gneiss followed by ferruginous infiltration, or, what may be called for want of a better term, lateritization. Dr. Benza was no doubt misled by appearances; for the hill is on certain views flat-topped, as by a capping of some other rock than that of the body of the hill, though not with the scarped edges implied in his descriptions; and then there was all the tendency to seize on such an exposure of lateritoid rock as being only a further occurrence of a formation which is so strongly developed along the greater part of the eastern coast. The facts of the case are that there is no capping on the hill, neither is it flat-topped for any breadth or length; on the contrary, it is rather rugged with the outcropping edges of nearly vertical strata of quartzose and garnetiferous gneiss striking nearly east and west; while certain more easily weathered beds have on their exposed faces put on the semblance of laterite.

[1] Vol. V., 1837.

[2] See Memoirs G. S. of I. XVI., Part 3.

It may be that isolated occurrences of the Madras coastal laterite exist, or that even a very different form of deposit, shortly to be described, may be representative of it; but such other lateritoid rock as I did see is similar to what has been described, or is the result of another very common agent, namely, ferruginous wash by which all sorts of debris may be cemented into a more or less hard conglomerate or breccia.

Recent and Post-Pliocene Deposits.—Under this head come blown sands, newer alluvium, lateritic wash, surface soils or other surface accumulations of rock debris, and some peculiar red sands, most of which, with the exception of the alluvium, in so far as it bore on the particular object of my visit, came but slightly under my notice. The blown sands are only very local in their accumulation occurring for the most part as a very narrow thin belt, or as occasional strong drifts blown inland for some distance up the valleys between the coastal ranges of hills, or even up the slopes of some of these ranges themselves. A very noticeable and big drift occurs between Vizagapatam and Waltair, which commencing as a slight shore edging of dunes at the outflow of the Hanavantumaka stream at the northern end of the Waltair ridge, keeps gradually but slowly increasing in width down to Scandal Point when it suddenly spreads westward up the little ravine of the Club-house *nala* and so well up along the southern flank of Rock Hill, completely filling up the wide hollow between this and the next hill to the south at Vizagapatam and ultimately plunging down the western slopes to the edge of the back-water. At the same time, the shore line of sand heaps is continued on to the end of the rocky spit on which the native town and fort are built. Local opinion is divided as to where this great drift came from, a strong idea holding ground that it must in some inconceivable way have drifted from the lagoon side; there can be no doubt however of its having been blown inland from the sea-shore by the strong north-east winds, the effect of which was deadened by the heavier rains, while a good deal of the sand is drifted back by the drier winds from the west and south-west. The seemingly overwhelming aspect of this great tumbling sheet coming in over the saddle between the two hills, is very striking from the low lagoon level. It is curious too to reflect how this apparently fortuitously stayed sand drift is after all perhaps the very saving of the town in one respect, namely, as regards much of its supply of fresh-water; for all the shore wells, of which there are many, and some of those on the back-water side, are dependant on the moisture absorbed by it.

Waltair Red Sands.—Considerable local interest has been long centered in a remarkable and puzzling bright-red sandy deposit occurring over most of the northern half of the Waltair rocky ridge. The deposit itself is an even-textured, rather fine-grained, tolerably well compacted or coherent but still soft, slightly clayey sand; or rather a thick accumulation of fine white quartz sand, having a very slight admixture of black iron grains, held together by a thin matrix or medium of dark-red ferruginous clay. It shows no lamination; so that at first sight it struck me as possibly an old blown-sand compacted by ferruginous infiltration, a view which was however effectually dispelled by my finding a thin skin of pebbly debris forming its base in the few places where its junction with the

rocky floor is seen. It has been likened, and not without reason, to the material of the ant-hills so common over all red sand tracts. The physical aspect of the deposit is also noticeable; for it spreads out from the northern flanks of the rugged Rock Hill as a broad high down the seaward slope of which is abruptly denuded and deeply scored by a set of short and steep-sided gullies giving passage to the many strong water-courses of the upland prior to their short run across, or absorption by, the shore belt of blown-sand. This high-lying red-sand tract is also separated entirely from the Kailassa hills to the north by the valleys of the Hanavantumaka stream, and the backwater drainage on the western side.

The base and slopes for a considerable height, 100 feet or so, of the Bimlipatam hill are also plastered over as it were by a similar deposit, the inner shore for some distance to the south of the hill being strongly covered and marked by it. Other patches shew at intervals, but not so prominently, further northward towards the Chicacole river.

I suppose the features which strike most people are the brilliant red colour as contrasted with the dark rock forming the core of the ridge and the great pale coloured sheet of blown-sand; the suddenly developed and deeply cut little gullies; and above all the isolation from any apparent source for the deposit by denudation of loftier ground, for by no conception could the material have been derived from the wearing down of Rock Hill for instance.

It is just this isolation and prominence of display which have, I think, had considerable influence in distracting attention from the very common and prevalent occurrence of a similar deposit not only elsewhere in the district, but over the greater part of the eastern low-country of South India: it is only necessary to go some 4 miles along the road to Vizianagrum to find red sands with similar features of denudation very well displayed beyond the village of Nellur, a short distance off the road on the left-hand side; and many other tracts of a like kind may be met with further inland, even right up to the base of the Galikonda range 30 miles west of Vizianagrum. Indeed, were the Vizagapatam district lowered a hundred feet or so, one might picture the sea baying in among all the beautiful hills and ridges and lapping alongside of many a red-sand tract at their feet similar nearly in every way to that of Waltair. Only, the proviso must be here made, that it was not necessarily lowering of the land, but rather elevation which helped to give its isolated character to the Waltair tract.

In other words, I would say that this tract and the others on the same coast are but remnants of the red-sand and gravelly deposits formation so prevalent all over the coastal plains of Southern India, particularly round the hilly regions in the Trichinopoly, Salem, and South Arcot Districts; or in the neighbourhood of the quartzite hills to the north-west of Madras itself; or in the Cuddapah and Kurnool districts; or, again, over much of the Godavari district and up the Godavari river valley, and which, in so far as they have yielded numerous palæolithic stone implements, belong presumably to the older or post-pliocene alluviums.

Here, in Waltair, it is merely a sandy deposit, at least none of the underlying or associated gravels, so common in other tracts, are visible; but there can be little doubt that it is of the same kind and age as the deposits indicated whether it was laid down as a great sand bank partly in fresh water, or in the sea

which once stretched over a considerable portion of what is now the Vizagapatam low-country. The colour is more intense certainly than I have ever seen among the inland tracts, but that may be due in part to contrast with the associated colours of sea, sky, rock, sand, and vegetation which themselves are usually intense. Proximity to marine atmospheric influences may also have had some effect. The curious denudation is on the other hand quite a common feature in the inland tracts where there is nearly always a broad plain, or gently sloping and broad terrace across which shallow nalas pursue a devious course much like those on the smaller scale at Waltair; the outer edge being nearly always abruptly denuded into sharp steps and little cliffs broken by the numerous gullies and rifts leading off the gathered streams of the upper levels.

The Waltair tract is however unique in its isolation, and in the fact of the sands being piled up or spread out over so high a part of the ridge; the two rocky hills already described having no very decided elevation over it. I can only venture to suggest that this isolation is either the result of considerable denudation of a great bank which formerly extended northwards across the Hanavantumaka stream and on to the Bimlipatam hill; or preferably that localized sand banks were piled or collected around the then sunken hills, in postpliocene times. The subsequent elevation of land involved in this view is considerable, at least 200 feet; but that is only in accordance with the evidence afforded at many other places in the Madras low country: notably by the great shingle banks far inland on the right bank of the Penner river in the Nellore district, or the much huger and thicker ones gathered round the foot of the Nagaloparam hills north-west of Madras.[1]

Crystalline or Archæan Rocks.—During the survey of the Kistna and Godavari districts in former years, I had found that a presumably newer and more decidedly bedded form of gneiss to that usually met with in the Madras Presidency began to show in the neighbourhood of Bezvada, forming the group of hills there narrowing the passage of the Kistna to its proper delta. These Bezvada gneisses,[2] as I then called the subdivision embracing the many varieties of essentially garnetiferous and schistose rocks, are continued all along the eastern faces of the hilly portions of the Godavari district into that of Vizagapatam in a generally north-eastward direction; gradually widening out

[1] While on the subject of change of land level, it may be as well to notice a prevalent idea that depression is now going on, or at least has taken place within the memory of man. It is generally believed, for instance, that a cave at the base of the Dolphin's Nose headland was once approachable by a path now covered at all tides by the sea; and the Revd. Dr. Hay of the London Mission was said to have actually made the journey to the cave in his younger days. On writing to my very esteemed friend, he replied: "When I came here 45 years ago, old men told me that when they were boys they could walk round the Dolphin's Nose. I have no other evidence of the fact; but at the time I refer to, the sea was rapidly encroaching on the land and had reached the European lines on the south side of the battery. It was then that Captain, now Sir, Arthur Cotton threw down those groynes, some six or eight of them. Between them the sand was raised again in a very short time and now there is a good gravelled road all along the beach which the tide never touches. An immense accumulation of sand was also floated seaward from the entrance towards the Custom House, exposing old wells, &c."

[2] Memoirs Geol. Sur. of India, Vol. XVI, Part 3, p. 12.

on either side, but always nearing the coast, until not far beyond the northern limit of the former district they form some picturesque hills on the sea-shore and henceforward become the prevalent rock of the country from the coast to well beyond the edge of the western hills or mountains of the Goluconda (or Golkonda), and Galikonda ranges bordering on the State of Jeypore. Perhaps, under this greater, or rather universal predominance of such rocks in this district, the term Vizagapatam gneisses might be more appropriate than the one I had originally adopted; but, at best, the selection of terms as yet is a mere matter of convenience, while *garnetiferous gneiss* is about as descriptive a designation as can be applied. At the same time, the occasion has not yet arrived, nor indeed have the rocks been closely enough examined or studied, for the placing them with any definiteness as a group or subdivision in the crystalline series; though it may be said that they lie in such a manner with regard to the other gneisses to the north and westward, and present such features of constitution and lesser amount of alteration or metamorphism that they may well be considered as one of its newer subdivisions.

The presence of common brown or purple-brown iron garnets (mostly weathered or more or less decomposed into rusty brown masses) in greater or less abundance—rarely absent altogether—is the striking accidental characteristic of the many varieties of gneiss. A further characteristic is that the felspar is very often that variety or species called *Murchisonite*, a peculiar brilliantly glistening (when in good sized-masses) bronze red, flesh-coloured, or even white mineral most easily cleaved in two directions sometimes with curved faces; but whether in large masses or distributed in a coarsely crystalline granular way through the rock, helping greatly towards its reddish or purple brown colour. The different kinds of gneiss which may be picked up sometimes within a small area are numerous, but the more prominent of these may be reduced to some three or four which it will be convenient to designate temporarily; while any attempt which is here made regarding their relation to one another must be considered as very tentative indeed and liable to re-adjustment or even entire reversal in the detailed surveys to be made hereafter.

Kailassa gneiss.—The commonest and most prominently exposed form is a generally dark purple-coloured (weathering brown or red) massive but strongly foliated or rather laminated rock of white or grey quartz and reddish or pale coloured felspar with some mica, largely charged or scattered through with iron garnets of all sizes, either singly or in masses or in amorphous laminæ which are often well sustained. The garnets are sometimes fairly crystalline in form. The more quartzose varieties often weather into what looks like a coarsely laminated ferruginous sandstone spotted and blotched with rusted garnets, or with strong laminæ of those decomposed stones. Such gneisses mainly constitute all the larger ridges and groups of hills; such as the great Kailassa massif north of Vizagapatam, or the Dolphin's Nose range to the south, or the huge and lofty (nearly 2,000 feet) range of the Chota Himalaya or Elephant Hill to the north of Vizianagrum.

Vizianagrum gneiss.—A second well-marked but not nearly so common or well-exposed form is that on which the town and cantonment of Vizianagrum

are built. It occurs as a broad east and west band coming in from the westward plains, and immediately east of the town curves round northwards past the Phulbagh reassuming a western course under the southern flanks of the Elephant hill. It thus underlies the Kailassa gneiss of the upper part of that hill the beds of which are dipping to the northward at 30° to 50°; though a narrow band of the next variety to be described comes in between the two. It is a generally very massive grey or buff-grey (weathering nearly black or dark-brown) quartzo-felspathic gneiss, only very slightly[1] foliated; not at all unlike some of the hard massive gneisses of Southern India, and presenting much the same smooth-haunched hills the rounded contours of which are occasionally broken by groups of loose disjointed subcuboidal and tabular blocks, or by occasional tor-like masses. Several small but conspicuous hills of this kind lie to the westward and north-westward of the cantonment. A tract of lower and more rugged knolled outcrops of a coarser and rather granitoid variety of the same rock lies to the east and north of Vizianagrum itself. The strike is, as already stated, about E.—W. for the cantonment and town range, the dip being high to southward or even vertical: and it was in such high dipping and hard rocks that the attempt at an artesian well was made. Occasional bands of more felspathic constitution or even seams of almost pure white *murchisonite* are associated with this variety of gneiss.

Quartzose Gneiss.—It is unfortunate, as far as uniformity of nomenclature is concerned, that I cannot give a local name to this variety; but this is hardly worth consideration where the rock is so easily recognizable by its constitution and by the manner in which it streaks the surface of the country with its conspicuous white reefs and ridges, particularly in the open country between the Kailassa and Elephant ranges, or again in the wide tracts to the north-west in the direction of the Bobbili territory. The most conspicuous outcrop is a long low mound-like hill a couple of miles to the north-west of Vizianagrum. The white colour of this variety is remarkable, and this with the manifest ridgy outcrops has of course lent considerable weight to the idea that the rock is really a vein rock, and that the presumed quartz-reefs of Vizianagrum must of necessity be auriferous. That the development is not one of quartz-veins, though there has no doubt been considerable local infiltration of silica at certain points along-side and through the beds of quartz-rock themselves, is a fact beyond all question. The rock, however white coloured and amorphous it may be at places, is when followed for any distance soon found to be distinctly bedded, laminated, and sometimes granular even to the extent of being manifestly a highly altered sandstone. One only has to examine the outcrop of the upper band along the southern base of the Chota Himalaya, eastwards from the point where the ghat crosses it. Here there has been tremendous crush; and the rock in its conditions of amorphousness jointing and cleavage is scarcely distinguishable from a vein quartz, while it is rather twisted out of strike and is nearly vertical. To the eastward, however, the normal northward dip is soon resumed, and the change to a well bedded and laminar disposition is quite plain within a range of half a mile, even with two or three further intervals of violent crush.

As a rule, however, the rock is more a quartz-schist than a quartzite, that is, it

[1] See also Dr. Benza's account; previous reference, p. 59.

is seldom finely granular or compact, more generally coarsely crystalline granular and somewhat open textured consisting almost entirely of ruggedly crystalline particles or masses of white or generally yellow and ferruginously stained quartz confusedly massed together; but in well defined beds of all thicknesses. There is a certain admixture of white or pink felspar filling up the interstices which on weathered surfaces are hollow and give the rock the rough open texture it often presents. In some of the very coarse varieties, the irregular masses of quartz are half an inch across; and, on joint surfaces, these show in certain lights a sort of adamantine lustre, rather unusual in this mineral. Some of the beds are micaceous and schistose, as in the outcrops 5 or 6 miles N.N.W. of Bimlipatam: while there are also associated beds and seams of more or less felspathic constitution.

Such are the principal and most marked varieties of the Vizagapatam gneisses: at least these are they which would force themselves by their occurrence in prominent outcrops on the notice of the observer in a series of rapid traverses like those on which this sketch is constructed. At the same time, there must be many other varieties hidden beneath the superficial covering of the plains which can only be ascertained by close work. One of them, appearing perhaps more frequently than others, especially between Bobbili and Parvatipur, is an extremely coarse and sometimes ropy-looking rock consisting of thick ($\frac{1}{2}''$ to $1''$) but exceedingly irregular and broken twisted laminæ of quartz (with garnets), felspar, and mica (crowded with garnets). Mica occurs with the other laminæ too: so that generally the rock might be called an extremely coarse micaceous gneiss. The laminæ are seldom steady in the direction of the dip, that is, they are broken by corrugations, though more so on the strike. As a consequence, on cross fractures the aspect is given of a very coarse granite, porphyritic with big masses of quartz or felspar. Most of the milestones along the Parvatipur high road, beyond Bobbili, are of this stone, and look very like blocks of coarse porphyry.

Gneisses of the Galikonda hill tract.—An opportunity, under the guidance of Mr. H. G. Turner, C.S., the Collector and Agent of the district, was afforded me of visiting this region and of thus making a traverse as far as the verge of the Jeypore territory, over a considerable thickness of gneisses which by their lie appear to be subjacent to or older than any of the bands or subdivisions already described. They are, at any rate, all dipping to the east-south-eastward: at first on the skirts of the hills about Bodara and thence westwards to the first ascent (1,000 feet) below Raiavalsa, at high angles; and then at lower and lower inclinations until, in Devadimanda (over 5,000 feet) the highest station of the Galikonda ridge, they are lying so low as 30°. The rocks are still garnetiferous but not nearly to such an extent as is the case with those already described; while they are more decidedly quartzo-felspathic in their constitution and not so schistose though still well-bedded and laminated, and their colours are of correspondingly lighter shades. They must, for the present, be considered as belonging to the Vizagapatam series being still on the whole markedly different from the more massive and less foliated and older-looking gneisses of Southern India. The main ridge beds, however, run up at the low angle of dip given above, and give a steep and high craggy face looking out over the lower upland of Jeypore

to the west, thus exhibiting a break in the surface contour which may arise from a change in the character and even the relative age of the crystallines to the westward. Galikonda is the proposed hill resort of Vizianagrum, but as yet it has only received very slight attention in that way, partly from its distance, some 45 miles westward, and from want of convenient accessibility. The old Raiavalsa track in the direction of Jeypore passes over a lofty (over 4,200 feet) saddle a short distance north of the highest point of the Galikonda ridge, after which it descends again rather rapidly to a lower upland: this is now being made by slow degrees fit for cart traffic. Long ago, some enterprising official built a bungalow and planted a garden of various fruit-trees high up on the eastern slopes, but the garden only now remains the living and luxuriant result of that experiment. At a much lower elevation, about 3,000 feet and about half-way up the ghat, an experimental plantation for coffee, tea, cinchona, and other products has been started under the local Government, with I think fair prospects of success.

Crystalline Limestone Bands.—A very interesting occurrence in the gneisses of the hill tract is a series of apparently isolated outcrops of crystalline limestone which, irrespective of the industrial value they may come to possess, are pierced by swallow holes or caverns one of which is of considerable extent and magnificence. The southernmost outcrop within the range of our traverse is on the low saddle above the village of Nilgalgunta, 6 miles south-east of Devadimanda hill. There is a small cave here, lined with travertine but without any stalactites or stalagmites: other recesses are said to exist which are now blocked up. The limestone is of grey and dark-green or nearly black colours, the latter arising from a strong admixture of hornblendic minerals, generally coarsely saccharine, in thick beds having a high dip to E.S.E., with an exposed aggregate thickness of about 30 yards. Some 6 miles, to the N.N.E., a short distance beyond the village of Borra, a much more important outcrop forms a low hill through which the village stream passes by a series of swallow holes to the Peddagunda river. Formerly the subterranean channel was free, but within the last few years it became choked up; and, as a consequence, a small lake or tarn has been formed behind the southern end or headland of the limestone hill, the flooded waters of which have in time cut a temporary off-flow on its western side. Half way over the hill, going northwards, there is an opening to a cavernous shaft down which one can look into dim depths and from which issues the murmur of running water. A short distance further on, the path reaches the edge of the northern face of the hill where it overhangs a deep ravine in which the village stream again comes to light about 300 feet below. The hill thus traversed by a series of swallow holes is made up, as far as outcrop shows, of about 500 feet in thickness of generally massive and pale-coloured granular crystalline limestone, some beds of which in their fineness of texture and pure colour compare favourably with Carara marble; though, as a rule, the rock is more coarsely crystallized and of grey or dirty white colours, weathering dark or nearly black. The dip is high 50° or 60°, or even more, to the eastward with a N.N.E.—S.S.W. strike. As far as I could see, the band is lenticular, thinning out rather suddenly to the southward.

Borra Cave.—About 50 feet below the northern brow, a large but low entrance leads into a deep and lofty cavern having a rude dome-like roof opening to the sky above by the orifice already mentioned. Here, in fact, is a huge natural cave temple, bearing a rugged resemblance to the Pantheon at Rome, though, as yet, it contains only one god, Priapus,[1] represented by a fragment of stalactite. The roof is crossed or irregularly ribbed with thick short curtain-like masses of stalactitic deposit, only one or two of which, towards the sides of the cavern, are connected with the thickly grouped and large mammilated mounds of stalagmite forming the floor. The latter slopes rapidly down on the eastern side to a narrow cleft or rift along which the waters from the stream above pursue their still hidden course; this rift being generally in a plane of bedding. Further cavernous recesses are seen to occur upwards towards the dammed-up tarn, while on the other side, the existence of yet lower caverns is evidenced by gleams of light pouring in from the deep ravine in front to the depths of the side rift. We were only able to note the features of this great cave in a very rapid way. The single stalactite (6 feet long, and 4 to 8 inches in diameter) has been appropriated for the devotional service noted above, the cave being the resort at certain seasons of many pilgrims. There is one other pillar in the shape of a small stalagmite, 3 feet high and 8 inches in diameter, which is slowly rising from the floor by deposition from the drops falling at long intervals from the roof. The interior of the cavern is coated over with travertine, a dull cream-white compact semi-crystalline rock, the surface sparkling a little owing to minute sparry facets. The stalactitic festoons are beautifully fluted and wrinkled, while the huge fungoid and coralloid mounds of stalagmite are wrinkled in little waves of terracing, the mounds themselves being made up of successive shells with irregular cavities between.

A good deal of rubbish, the sweepings from the numerous pilgrim gatherings, lies collected among the stalagmitic mounds forming an uneven earth floor, but with no thickness; and this appears to be the only material in which any remains could occur otherwise than in the substance of the mounds themselves.

On a subsequent visit, as I am informed by him, Mr. Turner ascertained, notwithstanding that we were told to the contrary by the villagers, that this band of limestones is continued to the northward, and that it even bars the passage of the Peddagunda river itself by a wall some 20 or 30 yards wide which is pierced by a cavernous channel having two appertures on the up-side, each 40 feet high, one above the other, but not in a straight line. Further in, the hollow is only about 3 or 4 feet above the level of the water; and through it, Mr. Turner could by creeping in as far as possible and bending down just see the light coming in at the orifice on the down side. There is no particular show of travertine in this swallow hole.

From all Mr. Turner could gather by enquiry,—and curiously enough the villagers appear very reserved on the subject—there appear to be other caves or outcrops of limestone both in this neighbourhood of Borra, and yet further eastward at the foot of the hills. This Borra band and that reported to the eastward

[1] Presumably so at least, for the pillar of travertine is to all appearance a sort of '*lingum*,' and there was no authoritative priest or devotee at hand to settle the question.

would be, if continued northwards in the line of strike held by the gneisses, somewhat in the direction of other reported outcrops of calcareous rocks in the Salur Zemindari: and it is not improbable that the ultimate tracing out of them, as well as of a yet further outcrop (to be noticed immediately) to the north of Vizianagrum, may bring the Galikonḍa gneisses into a closer relation with the Kailassa band than my traverse of them has led me to suppose is the case.

Economic Minerals, (Graphite, Manganese ore, and Kaolin).—It has been long known that graphite occurs in this district and indeed at intervals also to the southward in this same zone or belt of garnetiferous gneisses, as far as Bezvada on the Kistna. I was unfortunate, however, in not being able to visit any locality where it occurs. By all accounts, it is not known to occur in any quantity or richness; the most favoured locality for production appearing to be in the neighbourhood of Salur, the chief village of a large zemindari at the foot of the western hills.

I was more lucky however, in ascertaining the occurrence of manganese ore which has hitherto, I believe, only been reported as occurring here and there among the lateritoid forms of decomposed gneiss and then only sparingly, more especially so, it is said, on the Bimlipatam hill.[1] About 6 miles to the northward of Vizianagrum on the road to Palkonda, after passing through the gap in the Chota Himalaya range and a short distance beyond the ford of the Konada river, there is a band of dark weathering somewhat siliceous crystalline limestones cropping out along the base and somewhat up the slope of the hill on the east side of the road, associated with which are two obscure exhibitions of manganese ore. The most obvious of these last is in a portion of the talus of debris (mostly of gneiss fragments) at the foot of the slope, where for several square yards the black and slaggy-looking material gives the idea of the place having been the site of an old iron-smelting community. A good quantity of this *psilomelane*, as it really is, has been dug out for road material; in fact, the road is metalled for some distance with this ore of manganese. I was unable to satisfy myself that any of the ore is *in situ;* the pits have exposed a covered portion of the limestones alone, and the large blocks and smaller masses of ore all appeared to me to be debris which had rolled down from above like the gneiss debris on either side. Somewhat higher up the slope but to the right, following the limestone outcrop, a portion of the latter rock is crusted over by a thin and irregular coating of black, black and pink, speckled and blotchy travertine largely charged with earthy manganese ore or 'wad' which may have been caught up by the calcareous waters in their sub-terranean passage, through or over the manganese lode.

The crystalline limestone itself is very hard and finely saccharoid, and crowded with small crystals of green coccolite; in thick beds dipping at 45° or so to eastward, with the lamination well displayed on weathered surfaces.

Specimens of the ore were submited to my colleague Mr. F. R. Mallet, who reports:—

> No. 1. Non-nodular ore from road-metal quarry. *Psilomelane.* Contains 67·7 per cent. of available peroxide.

[1] It is quite possible that closer search may disclose a limestone band in this hill, or at any rate a band of manganese ore whence the ore (probably pyrolusite) in the lateritoid rock may have been derived.

No. 2. Nodular ore from same locality. *Psilomelane*, in part at least contains 53·5 per cent. available peroxide.

No. 4. Earthy ore from slope of hill above. Contains 16·7 per cent. available peroxide, also some lime, &c.

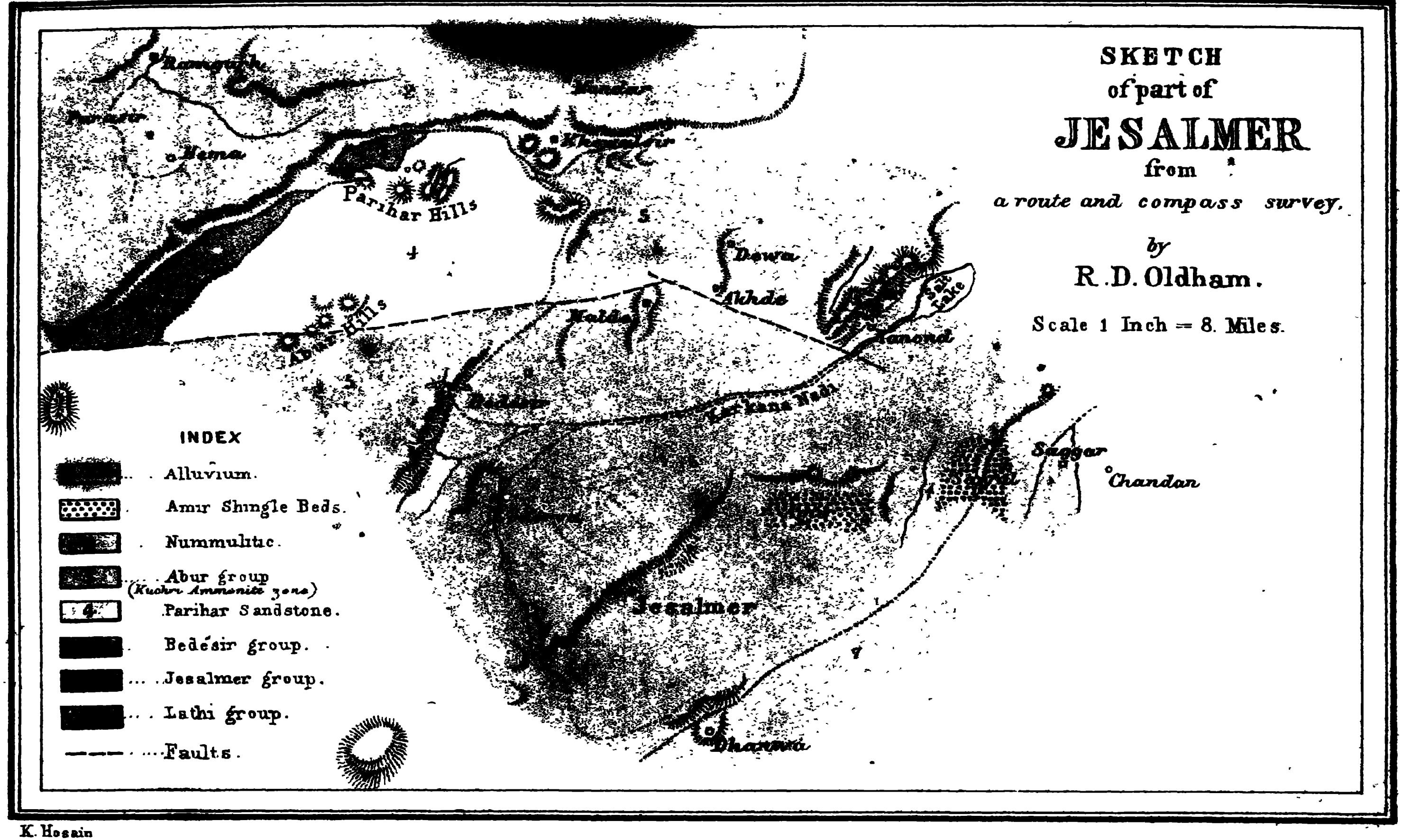
The latter specimen, taken from the travertine encrustation described above, is of very inferior quality : but No. 1 is remarkably good, coming up as it does to the average of the ore of commerce, which ranges at from 60 to 70 per cent. of available peroxide.

Traces of a similar development of crystalline limestone and associated manganese ore occur near Ramachandrapuram in the Salur zamindari; the high road, when it bifurcates to Bobbili on the one side and Salur on the other, being also metalled for some distance with debris of the ore.

Another industrial resource of possibly greater future value than either of the above is a more or less decomposed white felspar (? *murchisonite*) occurring in thin seams in the Vizianagrum band of gneisses which gives promise of a Kaolin of superior quality. It has been found here and there in the neighbourhood of the town in the digging of wells, and was, I believe, first brought to notice by Dr. Thos. Quinn, the State Surgeon, who also supplied me with specimens. Like many other so-called kaolins and pottery clays found in other parts of the Presidency, this local product has undergone a certain amount of trial at the Madras School of Art and even received rather favourable commendation from Mr. R. F. Chisholm, the then officiating Superintendent of that institution. A further consignment was asked for and sent down to Madras which appears to have given better results ; while a specimen of porcelain is said to have been prepared from it for the Maharajah's acceptance. Nothing further is however known of this consignment, and the development of the clay has fallen into abeyance.

Mr. Mallet was good enough to examine the specimens given me by Dr. Quinn, with the following result :—"*Decomposed felspathic rock from Vizianagrum.* When reduced to powder and mixed with water was only very slightly plastic. The mass was made into small bricks with sharp square edges, which, after drying, were heated in an injector gas-furnace. At a yellowish white heat the bricks began to bend, and at a full white heat were reduced to a semi-fused condition, the colour after cooling being pure white. The material is not a China clay, but resembles Cornish stone (a partially decomposed granite) which is largely used as an ingredient of the finer kinds of pottery. The absence of colouring matter in the Vizianagrum stone renders it suitable for use in a similar way."

These specimens were really only very partially decomposed, much of the felspar being crystalline and having the beautiful sheen or pearly lustre characteristic of *murchisonite ;* but I believe much more perfectly weathered or decomposed and clayey forms are procurable which may give better results. The doubt in my mind is as to the quantity available, for I did not see any indications of thick bands of such a rock.


SKETCH
of part of
JESALMER
from
a route and compass survey,
by
R. D. Oldham.
Scale 1 Inch = 8. Miles.
Parihar Hills
Abur Hills
Dewa
Akhde
Salt Lake
Kanod
Kakana Nadi
Saggar
Chandan
Jesalmer
Dharmsi
INDEX
Alluvium.
Amir Shingle Beds.
Nummulitic.
Abur group (Kuchri Ammonite zone)
Parihar Sandstone.
Bedésir group.
Jesalmer group.
Lathi group.
Faults.
K. Hosain

Preliminary note on the Geology *of* Northern Jesalmer (with a map), *by* R. D. OLDHAM, A.R.S.M., *Officiating Superintendent, Geological Survey of India.*

The country lying between the Arvalis and the Indus may be classed as one of our *terræ incognitæ;* even on the latest maps it is comprehensively styled a desert and the great objection which map-makers have to a blank space has been got over by scattering sandhills indiscriminately over the whole area. Sandhills are abundant and widespread, but there are also large tracts of country from which they are absent and which could even by comparison be called fertile, at least in those years when there is an average rainfall.

Broadly speaking this region may be said to be divided into three principal tracts: there is, firstly, the alluvial plain at the foot of the Arvalis dotted with rugged rocky island hills rising abruptly some hundreds of feet from the plain. Then comes a tract of undulating country in which there are large exposures of rock which rarely rise much above the general level of the surface, and to the west of this there is the rocky oasis of Jesalmer, marked by prominent scarps alternating with broad gently sloping plains. Geologically too the region may be divided into three tracts. There is first a tract where, excluding alluvium, the rocks are all the highly disturbed ancient beds of the Arvalis; then there comes a tract of the flat-bedded Vindhyan sandstones and limestones, and west of this there are the neozoic (secondary and tertiary) beds in Jesalmer. The geological and geographical divisions are nearly co-extensive and conterminous, but there are just sufficient exceptions to show that the features of the country are in part at least due to other than structural causes. Some of the prominent hills in the eastern tract are composed of the flat-bedded Vindhyan sandstones, and the western boundary of the undulating rocky plain overpasses the eastern boundary of the neozoic rocks. These divisions are very distinct about the latitude of Jesalmer, but to the north in Bikanir, where the rocks sink under alluvium and sandhills, they naturally disappear.

Any general account of this region would be incomplete without some reference to the sandhills which are found in all the sub-divisions and are particularly prominent and well developed in the desert-tract between Nagore and Phalodi. There are many problems of interest and difficulty in connection with these sandhills, not the least of which is their apparently capricious distribution and the apparently equally capricious exemption of large tracts from their presence.

Of the three geological sub-divisions the eastern one, that of the Arvali rocks, has already been described;[1] the Vindhyan area represents little of interest; and of the neozoic area a portion has already been referred to.[2] There remains the northern portion of the rocky oasis of Jesalmer which presents many features of interest and of which I propose to give a brief description.

The observations on which this paper is based were made during the loop cast, northwards from Jesalmer, mentioned above.[3] Under such circumstances

[1] *Supra*, Vol. XIV, p. 279. [2] *Supra*, p. 122. [3] Page 123.

detailed observation is as impossible as it would have been at variance with the object of my visit, and I shall in consequence confine myself very much to what may be regarded as more or less certain; some of the doubtful points it will be necessary to allude to, but most of them I shall pass over in silence.

The physical geography of this tract is characteristic and striking, being marked by numerous parallel scarps separated by broad grassy plains; in the north near the village of Parihar, there is a remarkable group of flat-topped hills which rise about 150 feet from the plain. These are the only isolated hills I know of in this region, and as they rise from an elevated plain they form a most conspicuous landmark visible even from the fort of Jesalmer. Two other peculiarities may be mentioned, one is the number of stream beds met with, one of which—the Karkana—has a course of about 45 miles, and is then lost in a salt plain which during the rains becomes a shallow lake; the other is the absence of sandhills, but few, and those small, are to be found at all.

East and south-east of Jesalmer, underlying the limestone, there is a group of sandstones characterised by the occurrence of silicified wood. These have been described by Dr. Blanford, but no special name given to them. I would suggest the "Lathi group," Lathi being a large village or town on the road from Pokran to Jesalmer, where the silicified wood is very abundantly developed.

From Jesalmer the route lay over the elevated rocky plateau of the Jesalmer limestones, and then descended into the valley of the Karkana; to the west of Lodowa is a broad alluvial plain with occasional outcrops of the limestones and sandstones of the Jesalmer group; this plain is bounded on the north-north-west by a very prominent scarp of the Bedesir group, rising to a height of over 100 feet; it is composed of pale purplish and reddish sandstone with which are some bands of hard calcareous sandstone, dark red ferruginous rock, and numerous thin bands of a hard black ferruginous sandstone that breaks with a glassy conchoidal fracture and rings under the hammer. In the sections I have seen, this rock occurs as thin bands, seldom more than $\frac{3}{4}$ inch in thickness, as partings in the softer non-ferruginous sandstone, and never forming more than $\frac{1}{50}$ of the whole thickness of the beds; but as the rock is practically indestructible its fragments, wherever it occurs, thickly strew the ground and give the country a desolate aspect not unlike that of a cinder heap or a recent lava flow on which vegetation has not had time to establish itself. The occurrence of these beds enables the group to withstand the effects of weather in a manner that makes its boundary with the Jesalmer group always take the form of a prominent scarp.

At one place, about 3 miles west-north-west of Lodowa, I was fortunate enough to find some fossils; they occur in a dark-red ferruginous matrix and consist of one or two species of *Ammonites* and *Belemnites* and a few *Terebratulæ* and some small free corals. It is impossible to say, without more detailed examination than is at present practicable, whether any of these are identical with Kachh species or no, but they do resemble some of the Katrol species, and curiously enough there is also a remarkable similarity in the matrix.

The boundary between the Bedesir group and the next above it is difficult to draw, as it is not marked by a scarp, and I have been compelled to take the limit of the black ferruginous sandstone as the limit of the two. This group I

have called the Parihar group as a provisional name, but in lithological characters it closely resembles the Umia group of Kachh, and seeing that the Bedesir group contains fossils resembling those of the Katrol group, and that the Jesalmer limestones are the equivalents of the Chari group, it seems probable that we might apply the Kachh names to the rock groups of Jesalmer, yet in the absence of more detailed examination such a course would hardly be justifiable.

The Parihar group consists principally of soft white felspathic sandstones, occasionally calcareous or slightly ferruginous. They decompose so easily that the country they occupy consists for the most part of level or nearly level sandy plains covered with a sugary sand, the sugary look being due to the angular shape and transparency of most of the quartz grains. Besides the soft sandstones there are some beds of a hard glassy rock, which breaks with a conchoidal fracture and should perhaps be called a quartzite; similar beds are known to occur in Kachh. In Jesalmer they always form hills, the most conspicuous of these being the Parihar hills, already referred to, which are capped by beds of the hard glassy sandstone, all the rest of the hill being formed of soft sandstone of the usual type of the Parihar group.

To the south of the Parihar hills is a group of hillocks, about 50 feet high, composed of this same rock. The southernmost of these appears to belong to the Bedesir group of rocks, and owing to its induration and a peculiar structure which gives it the appearance in one place of being composed of vertical beds, it seemed when first seen to be an inlier of the Arvali quartzites, an opinion which examination soon showed to be untenable.

At the Parihar hills the glassy sandstone may be seen in places distinctly overlying the nummulitics, but as I never saw any similar bed interbedded with the nummulitics, this would seem to be due to slippage of the hard bed from a higher to a lower level over the surface of the softer and more easily weathered nummulitic sandstones.

Above the Parihar sandstones there comes another group of sandstones, shales, and fossiliferous limestones, the latter weathering a dark-red colour. In this group there is a very conspicuous fossiliferous band, the fossils being all, except the oysters, converted into a yellow substance, which shows out conspicuously against the red matrix. This is Mr. Blanford's Ammonite bed of Kuchri,[1] but as this village is not on the group at all, and as the rock is known throughout the country by the name of "Abur stone," it would be better to use the name of that village for the group. The stone has a sort of semi-sacred character, blocks of it being quarried to place in the thresholds of the temples.

The next rocks overlying the Abur group are of nummulitic age; where crossed by Dr. Blanford in 1876, they form a conspicuous scarp, which extends as far north as the Parihar hills; here it becomes much less conspicuous and bends round to the eastward. The thinning out of the nummulitics is very marked, for the scarp at Abur is full 100 feet high, while at Khewalsir there are not more than 50 feet of beds exposed, and the lowest of these is higher in the series than any bed in the Abur scarp.

On top of the nummulitics there comes a band of a ferruginous rock, very like

[1] Rec. Geol. Surv. Ind, X, 16 and 20.

laterite; whether this belongs to the series or no I cannot say. I have never seen it overlaid by any beds of nummulitic age, but, on the other hand, from Ramgurh to Khewalsir the beds immediately underlying it appear to be identical; this would point to a conformity. Nothing resembling it was seen in the small outlier of nummulitics at Kotri near Koilath in Bikanir.

In the Bikanir outlier, and again at the village of Mandar, about 5 miles north of Khewalsir in Jesalmer, there occurs a very fine-grained unctuous clay or fuller's earth which is largely exported; it is the "Multáni mitti" of up-country bazaars.

To the north of the village of Mandar, just mentioned, the nummulitics sink below an alluvial plain, and about 8 miles further north the sandhills are said to begin.

On the road to Jesalmer, at Sawal village and again at Amir, there are large patches of pebbles derived from a conglomerate whose mode of occurrence is so deceptive that at first sight it appears to be interbedded with the sandstones of the Lathi group, but a careful examination showed me that they are of much later date and quite unconformable. The pebbles are all of local origin, being for the most part, rounded quartz pebbles derived from the sandstones of the Lathi group mixed with some less perfectly rounded pieces of ferruginous sandstone, silicified wood and a few of the characteristic yellow Jesalmer limestone. There is no direct evidence of the age or mode of origin of these shingle beds, but I would take them to be sub-recent and very possibly marine littoral deposits. It may be remarked that they occur on the boundary between the second and third of the geographical tracts into which I have divided the desert, and it is by no means impossible that the sea may have extended over the country east of Saggar and Sawal, while Northern Jesalmer was dry land. The only evidence I know of against this is the existence of a low scarp of Vindhyan sandstones at Pokran; but as this appears to lie along a line of fault it may be due to a differential movement at the surface and of quite recent origin.

There is yet another rock which must be mentioned. Near the summit of the Parihar hills, and again on the flanks of the Abur hills there occurs a peculiar compact generally pinkish limestone, or more properly limestone conglomerate, marked with concentric colour markings which surround the fragments of limestone of which it is composed; some of these fragments may occasionally be seen to consist at the centre of the yellow nummulitic limestone, while the outer part has become converted into a structureless and much older-looking rock. This is by no means the only locality where this rock occurs. Throughout my tour I was constantly meeting with a similar rock which usually contained large fragments of quartzite, in some localities angular, in others rounded. It is one of the puzzles of the region, for while its lithological character would lead one to consider it to be very old—at least as old as the Vindhyans—it appears to rest impartially on everything from the Vindhyan sandstones to the alluvium. Without more detailed examination it is impossible to say what it is, nor even whether in spite of the general resemblance of different exposures, it may not be of very different ages.

Notes on the microscopic structure *of some specimens of the* Malâni rocks *of the* Arvali region, *by* COLONEL C. A. McMAHON, F.G.S.

When reading Dr. Blanford's interesting account of the Malani porphyritic felsites,[1] I was struck at once with an apparent resemblance between them and some felsites observed by me at Tushám.[2] On mentioning this to Mr. Medlicott, Director of the Geological Survey of India, he was good enough to send me some samples of the Malani rocks collected by Dr. Blanford. Pressure of other work prevented my studying these specimens in detail at the time, but I have now done so, and offer the following remarks on the result.

I shall briefly describe the petrological character of the sample specimens in the first instance, and then conclude with a few comments thereon. The numbers quoted are those of the Geological Survey.

No. 41-62.—A dark grey, compact, almost flinty-looking felsite with extremely minute blebs of quartz dotted over it. Sp. G. 2·62. From a bed 30 miles west of Balmir.

No. 53-62.—A very light coloured, greenish-grey felsite dotted over with very numerous, but small, and very irregularly shaped porphyritic crystals of felspar. The matrix has a highly porcelanous appearance. Some extremely minute blebs of quartz may also be seen. Sp. G. 2·53. From near Pokran, 90 miles W.N.W. of Jodhpur.

M.—These specimens, though very different in macroscopic aspect are so similar under the microscope that they may be described together.

The ground mass, in both reflected and transmitted light, exhibits a very beautiful and decided fluxion structure. Between crossed nicols the base breaks up into micro-felsitic matter in which countless multitudes of minute specks of quartz shine like stars in the milky-way. These minute specks run together, here and there, forming nebulous clusters void of sharp or regular outlines.

Under high powers the base of No. 41 is found to be filled with countless opaque microliths, for the most part in shapeless dots, and flocculent greenish matter. The former is probably magnetite dust and the latter imperfectly crystallized amphibole. The latter is absent in the case of No. 53. These embryo microliths often cluster together and form wavy strings running with the lines of fluxion. These latter are due, apparently, to the imperfect admixture of felsitic and silicious material in the base. The lines of magnetite dust are deflected by the porphyritic crystals and cluster round their edges.

The base contains porphyritic crystals of orthoclase and free quartz. The felspar is very opaque. Some of the crystals present regular crystallographic forms; others are apparently in a fragmentary condition, whilst most of them are twinned.

Some of the quartz exhibits the remains of crystallographic shape, but, as is usual in this class of rock, it gives evidence of having suffered corrosion and partial remelting, being in more or less rounded blebs.

[1] Records Geol. Sur. Ind., X., 11-17. Manual, p. 53.
[2] Records Geol. Sur. Ind., XVII., 108.

No. 41 contains some sphene and magnetite, or ilmenite, the latter being much corroded. No. 53 contains a little hæmatite. The opacity and pinkish colouring of the felspars appears to be due to the dissemination of oxide of iron through their substance. In No. 53, the porphyritic crystals of felspar are much larger than the granules of free quartz. In No. 41, one of the grains of quartz contains a few liquid cavities with moving bubbles.

No. 45-62.—A felspar porphyry of reddish colour, from Balmir. Sp. G. 2·64.

M.—This rock under the microscope has, in some respects, the aspect of a trachyte. Microliths of felspar are numerous in the ground mass which also contains crystals of apatite and the altered remains of what appears to have been hornblende. Much of the iron present has been altered to a reddish oxide.

The slice contains no free quartz, but porphyritic crystals of orthoclase and plagioclase, corroded and eaten into by the solvent action of the base, are numerous. Zonal structure is apparent and the triclinic felspar appears to be oligoclase.

No. 46-62.—An amygdaloidal-looking rock with a purple-grey matrix. Veins of epidote are to be made out in it here and there. Sp. G. 2·68. From Balmir.

M.—Judging from the structural characters brought to light by the microscope, this rock approaches the basaltic type. It is not a true basalt, for it contains neither olivine nor augite; but its structure is that of a basic lava, for it consists of multitudes of micro-prisms and microliths of felspar disseminated through a devitrified glassy base. The latter is quite opaque when examined with ordinary powers, but, with the aid of high powers, it is seen to be composed of very minute translucent and opaque grains which are probably inchoate augite and magnetite.

The whole of the felspar appears to belong to the triclinic system. It is much decomposed and altered. The rock contains irregularly shaped spaces stopped with prehnite, epidote, calcite, and some opalescent quartz.

This rock very much resembles some of the basaltic lavas collected by me near Clermont Ferrand in the Puy de Dôme district of Auvergne, the habitat of the species of trachyte called domite. Some of the basaltic lavas from this locality contain much olivine and augite; others again, judging from the thin slices of them which I have examined, like the Balmir specimen, contain no traces of these minerals.

The Auvergne rock abounds in vesicular cavities of very irregular shapes and has a micro-granular base starred with microliths and micro-prisms of triclinic felspar like the Malani specimen. The latter rock was, I apprehend, likewise a highly vesicular lava when it flowed from its ancient crater; but the vesicles have long since been stopped with secondary products of decay through the agency of infiltrated water. A comparison of the recent lavas of the Puy de Dome with this very ancient Malani lava affords another illustration of the truth, now generally admitted by English geologists, that the petrological characters of volcanic products afford no test of geological age.

In connection with this rock it is interesting to note that Dr. Blanford met with "a considerable outburst of basalt" between Lowo and Pokran, though, as he met with none of this basic rock associated with the Malani beds in the

Pokran-Balmir area, he did not consider the relation of the basalt to the Malani felsites at all clear. As the microscopical examination of one of the five Balmir specimens sent to me for examination, displays basaltic affinities, it seems not improbable that a detailed survey of the Malani rocks, at some future day, may show that as in Auvergne, so also in the Malani area, acid lavas graduate into those of basic type.

No. 38-62.—A syenite granite in which hornblende takes the place of mica. Sp. G. 2·54. From Jessai hill west of Balmir.

Viewed macroscopically, this is a pinkish-white, fine-grained rock, abundantly sprinkled with very minute prisms of hornblende.

M.—Under the microscope the quartz and felspar are seen to be in about equal proportions. The felspar is much clouded, and its pink colour appears to be due to the dissemination of a brownish-red oxide of iron.

In the quartz, gas inclusions and liquid cavities with moving bubbles are extremely numerous and vary much in size. Some are very minute; others again are visible with a magnifying power of one hundred diameters. I have never seen a rock in which liquid cavities were more abundant.

Blade-like microliths of hornblende, blue in transmitted light, are rather plentiful in the rock and are to be found in both the felspar and the quartz. The larger prisms of amphibole vary, in transmitted light, from a vandyke-brown to a clear blue, in a way that is highly suggestive of tourmaline, but its optical properties are not those of the latter mineral. The blue hornblende is probably glaucophane or an allied variety. Much of the hornblende is very opaque even in very thin slices. Sections of rather irregular six-sided prisms are visible, but the cross cleavage is obscure and all the prisms seem to be made up of bundles of microliths which give it, here and there, frayed ends and a somewhat fibrous structure. It is powerfully dichroic, but it does not polarize in brilliant colours. In reflected light the hornblende is black, or blue-black, and its hardness is such as to prevent the possibility of its being mistaken for biotite.

The microscope shows that this rock is of plutonic origin; that is to say, it must have consolidated at some distance from the surface. In structure it is quite granitic.

General Remarks.

I have already mentioned at the commencement of this paper that I was struck, on reading Dr. Blanford's account of the Malani beds at Balmir and Pokran, with points of resemblance between them and the felsites at Tushám on the northern borders of Bikanir. This impression has been confirmed by the comparison of specimens from both localities.

There is nothing in their geographical position to render the correlation of the Malani and Tushám beds improbable, but rather the contrary, for it will be observed on a reference to the geological map that accompanies the Manual of the Geology of India, that Tushám and the Malani outcrops are both to the west of the Arváli series and at nearly the same distance from it. The strike of the Arváli series is north-easterly. A prolongation of the Balmir-Balotra outcrop of the Malani beds in a north-easterly direction takes us to the Jodhpur-Pokran

outcrop of these beds; and a further prolongation in a north-easterly direction would take us to Tushám. Whether or not the Malani beds show between Jodhpur and Tushám cannot be said, as this line has not, as yet, been explored.

The geographical position of Tushám, therefore, taken in connection with the north-easterly trend (N.E.-by-N.) of the Arváli range, and the north-easterly outcrop of the Arváli series, rather favours, than otherwise, the supposition that the Malani and Tushám beds belong to the same series.

The strike of the Tushám rocks varies from N. 11° E. to N.N.E., whilst that of the Balmir beds[1] is N.W. At Balmir, the dip is only 20° to 25°; whilst at Tushám it is vertical. I do not think, however, these facts are fatal to the hypothesis of correlation, for they might indicate, not that the Malani beds are unconformable to those of Tushám and are of different geological age; but that the beds at Tushám were more disturbed than those from 250 to 350 miles further south.

The points of resemblance between the Tushám felsites and those of the Malani series are not inconsiderable. It is true that most of the Malani beds are porphyritic, or at any rate the presence of porphyritic crystals of felspar is very characteristic of them as a whole; whilst, on the other hand, if we except the quartz-porphyry which is intrusive in the others, the Tushám rocks are not porphyritic to the naked eye; but as there is no great thickness of the felsites exposed at Tushám, this objection is not a fatal one, for it is open to us to suppose, either that the felsites are meagrely represented at Tushám, or that they lost in this locality one of the characteristics impressed on them further south. However this may be, it seems worthy of note that out of five specimens of the Malani series sent to me, one, namely, No. 41—62 (see *ante*), is macroscopically almost indistinguishable from No. 22 of my Arvali paper.[2] They differ only in slight shades of colour—a perfectly immaterial point. They are both dark grey, flinty-looking, compact, felsites with minute blobs of quartz dotted over them and visible to the naked eye. In specific gravity, also, there is no material difference between them, the Tushám rock being 2·63, and the Malani specimen 2·62.

Under the microscope, the resemblance between the two rocks is also considerable. The base in both is similar, and contains flocculent green material and porphyritic crystals of quartz and felspar. No liquid cavities were detected in the quartz of the Tushám specimen, but one of the quartz crystals of Malani, No. 41—62, contains a few.

Felsites appear to occur associated in intimate connection with plutonic rocks and also as true lava flows.[1] There is no doubt about the character of the Malani rocks, for beds of "unmistakable volcanic ash" were found associated with them;[2] but the question arises whether the felsite beds of Tushám are also volcanic. They occur on the west side of the hill of Tushám and they appear to be conformable in the direction of their strike to the sedimentary beds on the east side of the hill. Both the Malani felsites described in the preceding pages and those of Tushám exhibit fluxion structure (see my description of the Tushám felsites, Records XVI, pp. 108—110, Nos. 16, 18, and 22), and this structure i

[1] Rec Geol. Surv., X. 11. [2] Rec. Geol. Surv., XVII, 108.

characteristic of lavas, and affords, in a rock of this class, a *primâ-facie* indication that the rock displaying it flowed forth from the earth's crust as a lava.

The syenite-granite of Balmir (No. 38—62) has a much more plutonic aspect. This rock is probably alluded to at page 17, Vol. X of the Records G. S., and the rock there described is said to occur "intercalated in *large masses*" [the italics are mine] "with the porphyritic felsites." At Tushám and in its neighbourhood granitoid rocks also occur which are not true granites, but are granite porphyries. The association of granitoid rocks in both localities, namely, with the Tushám as well as with the Malani felsites, is noticeable, and forms one of the connecting links between the two. In both cases, possibly, the granitoid rocks may be directly connected with the lava flows and represent the roots, or deep seated portions, of these ancient volcanoes.

Without asserting positively the correlation of the Tushám felsites and the Malani beds, I think it worth while to suggest that future observations in the field may possibly establish the connection between them.

Dr. Blanford remarked that "the Malani rocks must be very ancient, but no idea can be formed of their geological position, as they are no where associated with rocks of known age except when underlying beds of comparatively recent date." This remark applies also to the Tushám rocks. They occur in an isolated hill piercing the sandy soil, the granite-porphyry also appearing as isolated hills, the whole group being many miles distant from beds of known Arvali age. A connecting link between the Malani and Tushám rocks may hereafter be obtained when the age of the sedimentary beds on the east flank of Tushám is ascertained. I have seen nothing similar to these beds in the limited area of the Arvali rocks which I have had an opportunity of studying in the field.

Memorandum on the Malanjkhandi copper ore, *in the* Balaghat *District, Central Provinces, by* WILLIAM KING, B.A., D.SC., *Superintendent, Geological Survey of India.*

Malanjkhandi appears to be the name of the low hill ridge, in the southern part of the middle saddle of which 3 or 4 quarries and a pit (about 30 feet deep, with two shafts close together and in communication near the bottom) have been excavated for ore. The quarries are now filled in with debris of the excavated rock in which faint traces of green carbonate of copper are recognizable. The pit is clean to the bottom where there is a little debris. These old diggings were brought to our notice in 1882 by Colonel Bloomfield, Deputy Commissioner of Balaghat.

I could not find any indications of a lode in the pit, only faint and rare traces of green carbonate as small strings and coatings in or on the rocky sides. A lode may have been worked out in these excavations: for it is hard to conceive how such deep working could have been pursued in the intractable rock without the

[3] Geikie's Text Book of Geology, p 186.

[4] Rec. Geol Surv., X, p 17. Manual of the Geology of India, p. 63.

incentive of thicker strings, or a lode; except on the view of forced labour under a tyrannical demand for copper ore at any cost. (I have formed a strong notion that the old and very extensive workings for lead in Kurnool and for gold in Wainad were to some extent the result of such demands.)

The quarries are tolerably large excavations; and they and the pit were worked along and down what might be considered the strike and dip of the rock. Other parts of the ridge, towards its northern end, have also been quarried though not to any extent.

I could not see any other ore than that of the green carbonate.

The vein stuff or matrix is part and parcel of the rocks composing the entire ridge; namely, a varying form of granular crystalline, or compact massive, generally white, though often brown or red-tinged from ferruginous staining, quartz-rock, having an indistinct bed-like arrangement (striking N.N.E.—S.S.W., and vertical or with a high westerly dip where the excavations have been made). The ridge indeed goes with this apparent bed-strike which however trends round nearly N.W.—S.E. at its northern end, and it is as far as I could see, completely isolated by covering superficial deposit from the massive granitoid and hornblendic (? greenstones) crystallines of the adjacent low country.

The country around, particularly to eastward, is seamed with less marked outcrops of like quartz-rock, some of which are however associated with clay-slate and altered sandstones.

There is no reliable history of the workings or the period of their desertion.

ADDITIONS TO THE MUSEUM.

FROM 1ST APRIL TO 30TH JUNE 1886.

Some impure graphite from Bettah village, Palamow.

PRESENTED BY MR. F. B. MANSON.

Fossil Wood (?) (mainly carbonate of iron, carbonate of lime, and carbonaceous matter), from the Sanctoria mine, Ráníganj coal-field. PRESENTED BY MR. I. J. WHITTY.

Galena, from Misroul, Tendwa, Hazaribagh. PRESENTED BY MR. W. CAMPBELL.

Beauxite (?), occurs "in veins underneath the coal strata," from Chitteedand, Salt Range, Punjab. PRESENTED BY DR. H. WARTH.

Specimens of plagiorite with quartz, from Wolfsberg, Harz; plasma mixed with 'sardoine'; cacholong from decomposed serpentine, from Baldissero near Ivrea, Piedmont; microcline broadly interbanded with albite (à larges bandes d'albite), from Département de l'Ain, France; microcline (amazon-stone), from Miask, Ilmen mountains, Orenburg, Russia; and microcline, from Bergen, Norway.

PRESENTED BY THE MUSEUM D'HISTOIRE NATURELLE, PARIS.

A sample of petroleum from the Khatan oil-wells, Sibi, Baluchistan.

PRESENTED BY MR. W. A. FRASER.

Some copperas from a drift near Pid Bungalow. PRESENTED BY DR. H. WARTH.

A log of fossil wood from the Sanctoria colliery, Raniganj field, in the 15′ seam, 270′ from the surface. PRESENTED BY MR. I. J. WHITTY.

A block of porphyry from the 'Olive' boulder bed of the Salt Range, having seven glaciated surfaces. PRESENTED BY DR. H. WARTH.

A collection of fossils, rocks, &c., from the nummulitic strata about the petroleum wells at Khatan, 40 miles east of Sibi, Baluchistan. PRESENTED BY MR. R. A. TOWNSEND.

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RECORDS

OF

THE GEOLOGICAL SURVEY OF INDIA.

Part 4.] 1886. [November.

Note on the occurrence of petroleum *in* India, *by* H. B. MEDLICOTT, *Geological Survey of India.* (With two plates.)

INTRODUCTORY.

There is very little indeed to be added to what has been already published upon this subject, but occasion demands that it should be noticed in connected form and under the light that has within the last few years been generated by experience in other regions. From the nature of the case this note will be chiefly made up with illustrations from abroad, as a clue to what may be looked for in India. The extension of railways on all sides has brought up a vote of urgency on the question of fuel, and our masters (through the press) are asking, 'What is the Geological Survey about?' The answer to this question has been within easy reach of those who chose to seek for it in the publications of the Survey. Years ago the little that can be learned from surface examination regarding the habitat of petroleum in India—in Upper Burma, Pegu, Arakan, Assam, and the Punjab—had been set forth, and until the fulness of time there would have been no use in repeating it. It is the practice of British Government at home to leave everything as far as possible to private enterprise, and it is not rightly understood that a total change of environment requires a change of system. The Survey is not equipped for or expected to carry out experiments, and without these on a more or less extended scale there was nothing further to be said upon the local conditions of petroleum. Now, however, thanks to our Russian friends, things have improved: the great extension of railways in North-western India and the scarcity of fuel there, have led to official investigations as to the hidden resources of that all-important material.

2. Already some success has been achieved in that direction, through the determination of Sir Theodore Hope, the Public Works Member of Council, to test the often-condemned coal of the Salt-range. Those nummulitic coal-measures had been repeatedly described and reported on, and provisionally pronounced to be unprofitable. They are well exposed throughout an immense stretch of country from north of Jamu in the Sub-Himalayas, through the Salt-range and the Suliman range into Sind. The strongest outcrop has been observed in the Jamu hills, far inside the fringing Siwaliks, but in that ground the measures are terribly broken and crushed. In the Salt-range they are of average development

and somewhat favourably placed for working. To the south they still further deteriorate, as seen at the well-known outcrops of Mach, in the Bolān pass, and of Lynyan in Sind. Other outcrops occur well to the north of the Salt-range, south of Attock in the Chita Pahar hills, where some money was lately wasted on exploration. In all these exposures, on very different strikes, the seam exhibits the same feeble development, which is certainly strange considering the very wide range of the coal-forming conditions here at that time; but from the abundant observations it was evident that no hope could be given of its improvement in any direction. The recent exploration in the Salt-range has not affected that judgment. As was to be expected, it has been proved by borings that the coal, such as it is, occurs under a considerable area in the Dandot plateau, easily accessible by drifts, so as to be economically workable under present conditions. A large consumption of imported coal at 3£ a ton would bring any sort of local supply into requisition. The best prospect, though not a very hopeful one, of a permanent supply of coal in this region lies in Mr. Oldham's recent announcement of the possibility of a field of Gondwana measures in Eastern Rajputana.

3. The same need has brought the petroleum question to the front, and the Government have begun explorations where the demand is most urgent, and with fair preliminary success. It is right to mention that this matter has not been neglected in the past: it was taken up seriously nearly twenty years ago, and an 'expert' was imported from America to examine the oil-bearing rocks of the Punjab. His reports were published in 1869-70; they were not encouraging, so the enquiry dropped. That mishap was to some extent due to the popular confusion on the genus 'expert'; and under present arrangements our rulers are of course only magnified representatives of popular notions. Operative (practical) functions are almost invariably connoted by the word 'expert'; and it would be well if the term could be confined to that sense, for though there is no essential reason why the scientific specialist should not be called an expert, there are marked distinctions between the two species, and the confusion of them is often fatal. When a man has to be hanged it is important that an expert should operate; but it would be a mistake to consult the hangman upon a puzzle in criminal law. Yet in matters mineral this error is continually committed by business men as well as by those who ought, at least through faith, to know better. The illustration from the course of law does not even sufficiently mark this blunder in mineral concerns; for here the defect is not only negative but positive—the man whose skill has been acquired in dealing with one group of conditions is actually led astray thereby in giving an opinion upon other conditions, his knowledge being solely empirical. Mr. Lyman's judgments seemed unduly cautious, or even partly erroneous, as I had occasion to point out three years ago when consulted in the matter.[1] There is, however, much excuse for anything that may have been said or not said even sixteen years ago on this subject, for although the petroleum business was then in full swing, the information derivable from such hasty experience had not been brought together. Even now the guidance to be obtained is most precarious; but the reason of it lies in the protean

[1] See Supplement to the *Gazette of India*, October 20, 1883, p. 1717. There is a misprint on the tenth line: for *holes* read *beds*.

character of petroleum itself. A little consideration of familiar facts will satisfy the incredulous that this excuse is not a professional subterfuge.

4. In these days of graphic papers, every one is familiar with the wonderful performances of the spouting wells of Baku and Pennsylvania. They form the popular standard of what a petroleum well ought to be. This is unfortunate; but a very little reflection on the fact thus plainly displayed ought to furnish the needful antidote to that hasty inference, and lead to a rational conception of what must be the variable and inscrutable distribution of petroleum. It needs no argument to show that a light and slippery fluid, which gushes out at the surface under a pressure of 300—400 pounds to the square inch as soon as tapped by a bore hole, would certainly not have stayed where it was if it could possibly have escaped, and that it would infallibly distribute itself under ground according to the access afforded by the permeability of the surrounding rocks. That pressure is not hydrostatic, as in artesian springs, communicated from a higher level within the same closed basin: it is elastic pressure, due to the expansive force of the gases that are always generated with the oil, so it is self-acting, independently of any structural arrangement of the enclosing rocks, although it is, as we shall see, controlled in many important ways by that structure.

5. Any useful knowledge we can have of mineral deposits depends on what we can discover as to the conditions of their origin and history, and for all minerals more or less of such knowledge can be attained; for petroleum, however, this knowledge is of little avail, because owing to its mobility it does not abide in its birth-place, but slips about in the most insinuating way wherever it gets a chance. It is something to know that there is a dominating effort to ascend; though of course, when the upward passage is barred, the oil would penetrate sideways or downwards under the elastic pressure of the gases which always accompany it. It would be easy to follow out these *a priori* considerations in connection with the familiar facts of stratigraphy, but the application will be better exhibited in actual examples.

NATURE AND ORIGIN OF PETROLEUM.

6. A real acquaintance with petroleum would require initiation into the mysteries of organic chemistry, for it is as protean in its composition as in its modes of manifestation; but it is desirable to have some notion of the substance under discussion. Homogeneous as it seems, petroleum is made up of an indefinite number of distinct compounds of carbon and hydrogen, or hydrocarbons; they are gaseous, liquid, or solid, and seem to co-exist in the crude material, for they are separable from it, without what is understood as decomposition, by careful fractional distillation and by treatment with appropriate solvents. The most important of these series of compounds are the saturated hydrocarbons known under the family name of the paraffins, represented by the general formula $C_n H_{2n+2}$. It begins with marsh-gas, CH_4, in which $n = 1$; descending, by the gradual increase of the carbon, with a corresponding increase of density, to the solid forms, the paraffins proper. Molecular science has scarcely yet mastered (or at least simplified) the intricacies of these compounds: within the several series there are numerous isomeric forms, *i.e.*, distinct substances whose empirical formulæ are identi-

cal, also polymeric bodies whose formulæ are integer multiples of the same primitive group. The volatile (inflammable) properties naturally increase with the proportion of hydrogen; but it is evident that specific gravity would be no safe guide on this point in a mixed oil, for its inflammability might be determined by the presence of a very small proportion of a lighter oil. Bitumen is the name in most general use for this whole class of substances. The solid forms are distinguishable from coal or other like matter by being fusible, and by their complete solubility in bi-sulphide of carbon. As occurring in nature the solid forms are called asphalt, while the more fluid forms of petroleum are distinguished as naphtha, and the more viscid, tarry kinds as maltha The manufactured products have a like classification: there are the naphthas, principally used as solvents; the less volatile distillates are the burning oils; the thicker kinds are much used as lubricating oils; the residual solids are paraffin, naphthalene, anthracene, &c. Petroleums differ much in the proportions they yield of those different products; *e.g* the California bitumen contains no paraffin, it also holds a small proportion of nitrogen; both facts have suggested the probable derivation of that petroleum from animal matter.

7. It is also desirable to know something of the supposed origin of the bitumens; and the questions are, whether or to what extent they are connate, or innate, or introduced, in the situations where they are found. They would seem *primâ facie* to be allied to coal: yet the essential dissimilarity of the two is what opens the door of speculation regarding petroleum. We commonly speak of 'bituminous coal'; but it is incorrect, as coals contain little or no bitumen, although bitumen can be obtained from them by destructive distillation, leaving a large residue of coke. The production of these oils in this way from shaly coal (unfit for furnace use) and from coaly shales, or 'oil-shales,' formed a very extensive industry before the petroleum discoveries set in, and it is still flourishing: the production last year in Scotland alone amounted to 62,712,000 gallons of crude oil. The origin of coal may be said to be completely known: by the slow transformation *in situ* of vegetable matter through the slow combustion of its less stable elements, producing a constant concentration of fixed carbon, with less and less of hydrogen and oxygen. It is found in every stage of transition from turf and carbonized wood down to anthracite, in which only the carbon remains. This process is completely natural and intelligible, and the puzzle is how in the case of petroleum, if it had an analogous origin from organic matter, the exactly opposite result—a concentration of the hydrogen element—can have been brought about, for the two are commonly quite similarly located and not seldom associated in the same series of strata. The contrast is exhibited by a comparison of their composition with that of cellulose, which is the basis of vegetable tissue—

	Carbon.	Hydrogen.	Oxygen.
Cellulose	44·4	6·2	49·4
Ordinary coal	84·6	5·6	8·0
Petroleum	85·0	15·0	...

8. This difficulty seemed so forcible that the connection of petroleum with organic remains has been denied and its origin as truly a mineral oil asserted. In 1862, the distinguished French chemist Berthelot succeeded in producing several of the familiar hydrocarbons by various processes, such as by bringing steam and carbonic acid into contact with highly heated metals having a strong affinity for oxygen. Conditions of this sort being reasonably assumable as occurring at great depths underground the possibilities of the theory were furnished, and it was strenuously sustained in the field by an able geologist, M. Coquand, from his study of the petroleum deposits in Roumania and Albania.[1] As against an organic origin he considers it final that no residual carbon is found with or near the petroleum; but while attributing the oil to a wholly independent source he insisted upon its contemporaneity with the deposits in which it is now found; he asserted that in all times, as now, petroleum found its way to the surface and there necessarily mingled with whatever deposits were being formed in the neighbourhood of its discharge. Under this view the oil would be in a half sense connate with the beds containing it, although provided ready made from a remote source. This is more or less plausible, and in the famous bitumen deposits in pliocene gravels at Selenitza in Albania, where the mineral has been extracted for many centuries, he seems to prove a deposit of this nature, such as might now be formed at the Pitch Lake of Trinidad, or elsewhere; but he insists on the same process for the petroleum of Roumania, where the oil occurs in two zones of stiff blue clay of eocene and miocene ages. The contemporaneity of the oil (or its elements) with the deposits seems undeniable, for although the rocks are much disturbed the oil keeps constant to the same beds, and it is hardly possible that it could have been injected into stiff clays after their consolidation; but it does not occur to him to explain how, under this theory, a comparatively light fluid was not floated away by the depositing waters. This objection however recurs, though in a less degree, for any theory of contemporaneous deposition. M. Coquand had a block of the fresh clay brought up from the pit for examination, and he found that the oil was not diffused through the mass, but distributed in little patches with thread-like connections.

9. The difficulty of petroleum being *innate* (by metamorphism), like coal, from organic remains in the beds where it is found, is equally admitted by those who deny its purely mineral origin: the apparently necessary residuum of carbon cannot be spirited away by theory. A considerable step in the coal-forming process is made in the decaying vegetation as it accumulates under more or less free access of air; a further great step is accomplished under a comparatively light covering of later deposits, and there is no stretch of imagination in supposing that gradual increase of pressure and temperature can accomplish the rest, the escape of volatile elements being all that is needed; but no plausible conjecture has been made for the removal of the surplus carbon or for its conversion by the access of free hydrogen, to form petroleum out of the same elements as coal; it has therefore been urged that this substance is *connate*, not innate. An apparently plausible conjecture on this side is, that petroleum is derived from marine

[1] Bull. Soc. Géol. de France, (2) Vol. XXIV, (1866-67), pp. 505-569, and Vol. XXV (1867-68), pp. 20-74.

vegetation, as coal is exclusively from land plants; and that the slow maceration it is subjected to during deposition under water may produce the required result. This view was well put forward by Mr. Leo Lesquereux in 1866.[1] He remarks that Algæ thrown upon peat do not leave any trace of organism, but the resulting compound is softer and of deeper colour; that Algæ heaped upon the shore promptly decompose into a soft black paste and then into a glutinous fluid which sinks into the sand; he even appeals to the green fat of turtles as derived from a diet of Algæ. He also refers to the frequent occurrence of petroleum in strata with fucoidal impressions. He regrets that Liebig was unable to supply him with any hints upon the chemistry of the process. Dr. Sterry Hunt, who is especially an authority on the chemical side, adopts this view in a general way.[2] He admits that the origin of petroleum may be referred to a particular transformation of organic matter effected in deep water where calcareous deposition is in progress, while similar matter in shallow waters loses a larger proportion of its hydrogen and forms coaly deposits (pyroschists). He alludes to the great bank of *Sargassum* in the Mid-Atlantic as a probable seat of such production.

10. It is true that Mr. G. P. Wall,[3] from his examination of the bitumen deposits of Trinidad, of which the famous Pitch Lake is but a waste-pool, satisfied himself that the asphalt is innate, being formed from the remains of terrestrial vegetation in the shaly sand where it occurs. He attributes its accumulation as irregular masses in the bedding, and the consequent loose texture of the shales, to the segregation that took place after the conversion of the diffused matter into bitumen. To account for his opinion he accepts as actual Bishoff's formulæ[4] showing how by giving off carbonic acid instead of carburetted hydrogen fossil wood might turn into bitumen instead of into coal; but there is something to be desired in his demonstration that such was the case. The evidence that has been principally quoted is Mr. Crüger's admirable study of some specimens of wood more or less changed into bitumen, but Mr. Wall does not show how far these were representative of the deposit, or that all the specimens may not have been what Mr. Crüger (*l. c*, p. 175) says some of them were, simply "rotten wood impregnated with pitch." There are lignites associated in the same upper tertiary deposits with this asphalt.

11. There remains the question whether petroleum may not be an interloper in its present locations. That it is so in some cases is beyond question, for it is found in force filling fissures in eruptive and crystalline rocks; and it goes without saying that since it reaches the surface it may (or must) take possession of any convenient receptacle it comes across in its ascent. This theory has thus a certainty to start with; and we shall see that it is as good as proven that the greatest known sources of petroleum were formed in this way—that the oil was not indigenous but introduced where now found. The question of origin remains open: whether by direct synthesis from mineral elements, or by distillation from fossil organisms; the conditions of distribution would be to some extent the same

[1] Transactions of the American Philosophical Society, Vol. XIII, (N. S.), pp. 313—328.
[2] Bull. Soc. Géol. de France, (2) Vol XXIV, p. 572 (1867).
[3] Report on the Geology of Trinidad: Memoirs of the Geological Survey (Colonies), 1860.
[4] Chemical and Physical Geology, Vol. I, pp. 281-88, (1854).

in either case. The distillate theory has been rather unfairly handled, the chief bone of contention being again the irrepressible carbon residuum. Because coal and pyroschists are found in their normal state in close proximity with petroleum, because the residual carbon is not found with or close by the oil, the possibility of derivation by distillation is denied. Or again, because all the rocks below a petroleum bed are not smudged with oil, the possibility of its having come from below is rejected. This latter difficulty is the least reasonable, as it assumes that the distillate would take the most difficult route to reach its destination, namely the direct one, across the bedding of the intervening rocks. Underground water does not percolate in this fashion, and why should petroleum, whether as liquid or as vapour? In the latter case too it seems clear that it would not be precipitated until it found its appropriate condenser, and there seems no limit to the circuit or the distance it might have to travel before reaching that resting-place. Then as regards the great crux, it should be remembered that there *are* immense stores of residual carbon in the older stratified formations, whether in the state of anthracite or of graphite, both massive and diffused. It can hardly be demanded that it should appear in the form of coke: it seems presumable that after all the oxygen of coaly or other organic matter had been eliminated, the final step in the production of anthracite or graphite, under the influence of gentle heat, would be the evolution of hydrocarbons. It has moreover been suggested that for marine animals and plants, which together supply no doubt the chief bulk of fossil remains, the proportion of carbon to be accounted for is much less than in the land vegetation forming the basis of coal. It is to some such action as this that Mr. Carll appeals as the origin of the great oil deposits of Pennsylvania which he well nigh demonstrates not to be indigenous (either innate or connate) in the deposits where it accumulated. As an objection to making this process universal, if so foolish an attempt were made, one might urge the impermeability of some rocks in which petroleum is found, such as the stiff clays of Roumania already referred to, or the occurrence of oil in the cavities of fossils in the midst of a dense limestone. Both these instances have reasonably been taken as evidence of indigenous origin; but indeed, when we find geodes filled with successive layers of minerals in the midst of compact basalt it is difficult to place limits upon the possibilities of permeation.

12. The foregoing notice of the current speculations regarding the origin of petroleum should be of some service, if only to explain the uncertainty that must exist as to its distribution in any particular locality. With so ample a store of raw material as is provided by fossil remains in the prodigious accumulations of stratified rocks; also, with the agency of conversion, by slow increase of pressure and temperature, provided in the changes to which those rocks are in every degree subjected, there is no excuse for appealing to the more or less occult resources of the earth's inner laboratory, so this view of the origin of petroleum as a 'mineral oil' has been generally abandoned, though it might be rash to assert that no such phenomenon ever took place. The fact that in its most prolific deposits the oil is not indigenous is the most salient result of past experience; but it is fully accepted that in some deposits it is so, and such is evidently a corollary of the approved mode of origin: the compulsion to leave its birth-place would be an

extra exercise of the conditions that brought about its formation; in many cases it would only be the surplus product that would have to find accommodation elsewhere.

THE PENNSYLVANIA OIL REGION.

13. The most extensive and most productive petroleum region as yet worked is that stretching as a long belt from Canada into Tennessee west of the Appalachian mountains in eastern North America. The total area of this region is estimated at 200,000 square miles. The great series of palæozoic formations, which have been crumpled up to form the mountain range, are practically undisturbed in the oil region, having only a gently undulating inclination, averaging 25 feet in the mile, in a south-westerly direction. In 1885 the yield of oil from this region was 21,600,000 barrels (of 42 gallons each), from 20,000 more or less productive wells. The richest fields occur in Western Pennsylvania, and a full description of them, by Mr. J. F. Carll, was issued by the Geological Survey of Pennsylvania in 1880. The section in figure 1 of the annexed plate I is reduced from one given in that work. It represents a distance of 225 miles. The vertical scale is 20 times that of the horizontal scale, so that the apparent dip of the strata is much exaggerated. The accumulated thickness of the formations amounts to 6,400 feet, extending from the upper coal-measures in the south-west down to the corniferous-limestone (bottom devonian), which forms the Black Rock outcropping in the Niagara river just below Lake Erie. In Canada this rock passes again underground and is the principal source of the Canadian petroleum; but oil is found at a much lower horizon, in the Trenton-limestone (lower silurian), where there is no underlying fossiliferous rock—a fact insisted on by Dr. Sterry Hunt as proving that the oil must be indigenous in this limestone. In the same contention this authority also shows that the Niagara-limestone (upper silurian) of Chicago at its outcrop still holds 4·25 per cent. of oil diffused in its substance.

14. Four principal oil groups are represented in the section, within a thickness of about 4,500 feet of strata, from the Bradford-sand in the north-east to the Mahoning-sand in the south-west. There are several other productive bands of less importance. The groups of strata in which these oil beds occur are more or less continuous over very large areas, the productive oil beds in each being much more restricted. In all cases these beds are sands and gravels, the output of the field being proportional to the porosity, thickness, and extent of the 'oil-sand.' These are very variable and irregular elements, as is always the case with coarse deposits. The thickness of an oil-sand has been found to range up to 120 feet. Owing to the innumerable borings that have been made, perhaps most of them without success,[1] the horizontal distribution of the several oil-sands has been very closely fixed; they mostly have an elongated shape, as is the habit with sand banks. The Bradford field covers about 133 square miles. In every case the oil-sands are overlaid by fine impervious shales. Throughout the greater part of the oil region there was little or no surface indication of the occurrence of oil in the ground, though, of course, such did appear at or near the outcrop of the oil-rocks. The

[1] Amongst these was the deepest well yet sunk in that region—Watson's Well, at Titusville, 3,553 feet deep, of which 2,263 were below ocean level.

most productive sources were, as might be expected, at a distance from where natural escape had been effected.

15. From the facts before us it is plain that the distribution of the petroleum in this region has very little to say to geological horizons in their particular (chronological) sense; but Mr. Carll notices an apparently important feature in its vertical distribution. He remarks that all the productive measures occur within a level zone of 1,500 feet; that although a large number of deep holes have been put down none have produced oil at a depth of more than 500 feet below ocean level, and very rarely at more than 2,000 feet from the surface.[1] Gas, on the contrary appears here to be a universal product, confined to no particular horizon or locality (*l. c.*, p. 111). These facts *primâ facie* suggest that the position of the oil was determined by a zone of condensation and of catchment of volatile products distilled from underlying rocks. The particular conditions would agree with this interpretation: coarse sand banks are the least propitious ground for the accumulation of organic matter, while such matter is known to be present abundantly in the shaly and calcareous strata underlying these oil-measures to a great depth. The notion that the oil occurs in crevices and cavities has not been confirmed by observation in this field, the porosity of the sands themselves is sufficient. Mr. Carll is careful not to propound these observations as of universal application, and it is obvious to the geologist how certain conditions might alter the figures of the problem, but it is certain that the results are the most important contribution as yet made to the question in hand. It is now generally accepted as proven that for the most part the petroleum with which the 'pools' of the eastern North American basin were so copiously charged, was not indigenous in those oil-sands.'

16. It is of greater importance for us to notice how essentially the wealth of these oil measures depends as much upon their actual as upon their original stratigraphical conditions—on the fact that the strata are still practically undisturbed. The formation of these pools depended upon the prior formation of the more or less isolated lenticular banks of sand and pebbles, and upon these being more or less hermetically covered by finer deposits; but the preservation of them depended no less upon that favourable arrangement being undisturbed. The permeability of strata is incomparably more easy along than across the bedding; an almost imperceptible film of finer deposit might exercise a very important control upon the circulation of fluids underground. It is evident that when strata become tilted and broken, the conditions of circulation are wholly altered; porous beds that before were lying flat, and safely covered over, become turned up and brought within easier reach of denudation, whereby they expose outcrops at the surface; or cracks are more or less abundantly formed, offering egress where before there was none. A fluid under elastic pressure must avail itself of such means of escape from its original prison-house. These conditions have been fully recognised in practice: in a paper read before the American Institution of Mining

[1] Mr. Carll (*l. c.*, p. 151) further emphasizes the fact that two oil groups are never found in the same vertical: the Warren group has never been found directly beneath the Venango group, nor the Bradford oil-sand directly beneath the Warren group. It is not quite clear whether only the oil is wanting, or also the sand beds: as only the former case would be 'remarkable' in this connection it is presumed that this is intended.

Engineers in September 1885, Mr. C. A. Ashburner, Geologist in charge of the Pennsylvania Survey, remarks—"That the absence of both petroleum and natural gas in our plicated strata east of the oil-regions is to be explained by the cracking of the rocks would seem to be evident, since the survey of the outcropping rocks and a study of the records of dry wells show that the oil- and gas-sands extend far beyond the limits of the area of the region in which any traces of oil or gas have ever been found. Even within the area where oil and gas-wells have been found the cracking or jointing of the rocks must have a potent influence upon the amount of oil or gas obtained in certain localities."

17. Very partial disturbance, such as these measures have undergone, may even help the concentration of the oil, which would naturally rise to the highest part of a bed that had undergone slight tilting or curvation. Hence the craze that so long prevailed regarding a connection of oil with anticlinal axes. To a certain point it is true enough; but on the other hand an anticlinal axis is the most likely position for fractures, and even were the rocks not broken this position is obviously the one to be soonest exhausted.

18. Although the immense energy displayed in developing the industry of the oil fields under notice has given us data for a fair understanding of their structure and extent, it is lamentable that some check was not put upon the prodigious waste of those great natural and national resources through the reckless competition of greedy adventurers. Forests are protected, although renewable; but in mineral resources, which are limited quantities, it is among men and nations a race of 'devil take the hindmost' in squandering all that can be laid hold of, heedless of the waste caused by the scramble. The most prolific of gushing wells ere long settle into pumping wells; the average life of wells in Pennsylvania is five years. Already there is notice of coming exhaustion in this great region: last year on the occasion already quoted, Mr. Ashburner remarked—"That the general boundaries of the oil regions of Pennsylvania are now well established, there is but little doubt; and that all the sand in which oil will ever be found in paying quantities are known and have been drilled through at different localities in the oil-regions seems quite certain, so that we can have no reasonable expectation that any new and extensive field will be found which could compare in area or in the amount of oil to be obtained from it with the Butler, Clarion, and Armstrong pool, the Oil City and Pleasantville pool, the great Bradford pool or the Allegany pool. * * * It is estimated that in July 1883 there were in the region 17,000 producing wells, the average daily product of which was 3·8 barrels. In July 1884, there were 21,844 producing wells, and the average daily product was 3 barrels; and in July of this year [1885] it is estimated that there were 22,524 producing wells, the average daily product being 2·5 barrels. A defined territory, a product inadequate to meet the demand of the market for the past eighteen months, a growing market and rapidly diminishing stocks, an increasing number of drilling and producing wells, and a rapidly falling daily average product from wells, are all significant signs of a certain decline in a great industry."

BAKU.

19. The only known petroleum region at all comparable as to productiveness with the great American basin is that of Baku, where the range of the Caucasus

ends at the Caspian sea in the peninsula of Apsheron. It will be instructive to see in what other features these unparalleled oil measures are alike. The geological information regarding the Baku ground is comparatively scanty, because, notwithstanding the prodigious output of oil, the workings are still limited within an area of five square miles. The wells too are of very moderate depth, the deepest as yet being only 840 feet.[1] This would seem to warrant the judgment that this spot can only be the natural focus of a very extensive oil region. In geological age the two measures are about as different as they could be, the American rocks being lower palæozoic, while those of Baku are middle tertiary; but we have already seen that the geological horizon has little to say in the matter. The rocks too are quite dissimilar, beyond the common characters that clays, sands, and limestones of every age must exhibit. The oil at Baku is held in irregular banks of sand between strong beds of clay, with some limestone. The critical feature of resemblance is that at Baku also the measures are nearly horizontal, and there can be no doubt that the profuse abundance of the supply is immediately due to this condition, and that the oil in these sands is accumulated from underlying or adjacent rocks. The strata, so far as visible at the surface, are remarkably wanting in organic remains. In figure 2 I have reproduced Abich's section of the Apsheron peninsula at the oil wells, from which it is plain that these are situated at the crest of a very flat anticlinal. The section is copied from the Mémoires de l'Académie des Sciences de Saint-Pétersbourg, Ser. vii, Vol. vi, of 1863, but it is quoted up to date as the authority, for which Abich's name is sufficient guarantee. The present (1885) annual output at Baku is given as 1,000,000 tons; the 100 wells now active yielding an average of about 32 tons per day A single well has given as much as 140 tons a day for ten years, the oil standing at 51 feet from the surface; it ultimately failed altogether. Here too incipient local exhaustion has been noticed; in a paper in the Mining Journal of St Petersburg for September 1885 Mr. F. Vasilieff mentions a marked increase in the proportion of water admixture,[2] indicating exhaustion of the oil; but in this region it would seem likely that there is ample room for extension.

COMPARISONS.

20. In every other description I can find of petroleum diggings all over the world, so far as intelligible, they differ from the two leading cases already given, in the circumstance that the strata are much disturbed.

21. The further exploration of the Punjab oil measures has recently been vigorously urged upon the Government by a distinguished officer, who has been ten times at Baku and made a special study of the petroleum workings there, and who has also examined the Punjab oil measures. His recommendations are based upon the striking similarity of the two fields. He observes that "unless a geologist or expert had actually visited the petroleum wells at Baku, I should not value his opinion for the reasons that I perceive a striking resemblance

[1] Vasilieff: September 1885.

[2] As this water is probably flooding water (from above), the symptom is not so bad as it might otherwise be.

between the country and soil near Gunda and that which forms the Aspheron peninsula." To illustrate this remarkable observation I have reproduced in figure 3 Mr. Wynne's section of the Punjab area, from Vol. X (1877) of the Records of the Geological Survey. It crosses the very place mentioned (Gunda) at a short distance north of Fatehjang; the oil occurs in the nummulitic strata, numbered 5 and 6. A comparison of this section with those of figures 1 and 2 will scarcely bear out the 'striking resemblance' asserted in the quotation just given: the oil measures of the Punjab are about as much disturbed as rocks can be, which fully accounts for the state in which we find the oil; for ages it has had free vent at the surface, the only check being the porosity of the containing strata. If the example quoted from Mr. Ashburner of the American oil measures as represented in the flanks of the Appalachians, were to be hastily taken as a precedent, there would be little hope for the Punjab oil; but the cases are not quite parallel, and with petroleum no precedent would be safe. Besides we have here the crucial fact that there is still oil in the ground, notwithstanding the exhausting conditions of the Punjab climate. But any prospect of even a distant approach to the Baku standard must, I think, be given up. All the Indian oil measures are in about the same geological horizon (eocene) and in much the same condition as to disturbance, the Irawadi region least so; but they vary greatly in apparent fruitfulness, the Punjab region being decidedly the least promising.

CALIFORNIAN REGION.

22. I have searched all the accounts I could find of the occurrence of petroleum in disturbed measures, for any hints that might be of service in exploring our Indian rocks, but with very little success. This is not surprising when uncertainty in every condition is the rule. Such works are moreover incomparably less extensive in every way—in area, in the number and depth of the workings—and have consequently received less attention. In America the next most important measures, but far inferior, to those of the Appalachian basin are found in the tertiary rocks of the coast ranges on the Pacific, chiefly in California. Information on this ground is very scanty. Even in the elaborate report on petroleum, drawn up by order of Congress for the tenth census of the United States in 1882, Mr. S. F. Peckham mentions the extensive operations of the Pacific Coast Oil Company, but regrets that he was unable to obtain any particulars in reference to the production of their wells. He has to refer to results in that region generally as confirming the opinion he had expressed after his exploration there in 1866, that "the expectation of extraordinary results, that will admit of comparison with those produced in Pennsylvania, must be set aside. The expectation of a fair return and a permanently profitable investment may be reasonably entertained; and the application of capital on this basis to this interest will make it of great importance to the State." The measures seem to lie chiefly in mountainous ground, in very disturbed rocks. There are frequent deposits of asphalt and of maltha at the surface from the evaporation of exuded petroleum. Even underground this effect is observed, and to be in direct proportion to the ease with which rain-water could percolate the strata. The oil primarily occurs in strata of shale, interstratified with sandstones of enormous thick-

near. Mr. Peckham mentions that he "nowhere observed the petroleum saturating the sandstone, although it sometimes escaped from crevices in it; nor was the bitumen held in crevices of large size nor under a high pressure of gas, as the disturbed and broken condition of the strata, folded at very high angles, precluded such a possibility." He considers the oil to be indigenous (innate) in the shales. In hilly ground, and in such rocks, the oil is often got at by tunnels, or drifts, for which practice a synclinal structure of the strata in the range is obviously the most propitious. The exploitation of this oil region is at present evidently held in abeyance by the profuse output of the eastern region; still Mr. Peckham estimates the yield for the census year at about 1,000,000 gallons.

EUROPE.

23. The most productive oil-ground in Europe seems to be along the flanks of the Carpathians—in Galicia, Roumania (Moldavia and Wallachia), and Transylvania (Siebenburgen)—where of course it has received due doctorial attention. Mr. Redwood[1] notes the production of crude petroleum in Galicia for 1883 as follows:—

	Cwt.
West Galicia—	
1. Sandez and Gorlice	91,500
2 Jaslo and Sanok	44,900
East Galicia—	
3. Sambor and Drohobycz	73,600
4. Kolomea	300,000
	410,000

There were then 3,500 producing wells. The third district produced in addition 105,200 cwt. of ozokerit (crude paraffin wax). The most productive ground of the Kolomea district was not opened until 1881, and at the end of 1883 it was reported to be yielding 550 barrels of oil per day within an area of 1,500 metres in length and 350 to 500 metres in breadth. The number and depth of the wells are not given. The oil-measures of Galicia occur at several different horizons in cretaceous and tertiary rocks: some of the latter correspond with those of India, and all are, like these, in highly disturbed strata.

24. In 1859 M. F. Foetterle[2] mentions that in West Galicia many wells, over 60 feet deep, produce at first the "not inconsiderable quantity of 12 gallons in half a day," the other half being apparently allowed for accumulation; the oil is skimmed from the surface of the water with which it percolates to the well. The oil comes from the crevices in a much shattered black bituminous shale interbedded with sandstones (eocene). He attributes the gradual decline in the yield to the slow natural process of production, which he assigns (without explanation) to the action of decomposing pyrites sparingly disseminated through the carbonaceous shale, under the influence of atmospheric agencies. Mr. Foetterle describes the wells at Boryslaw and Truskawice in East Galicia as in somewhat newer rocks in which the oil completely saturates a soft sandstone.

1 Petroleum and its Products: Journ. Soc. of Arts, Vol. XXXIV (1886), p. 812.

2 Jahrbuch d. k.k. Geol. Reichsanstalt, Vol X: Verhandlungen, p. 183.

25. Dr. von Hochstetter[1] describes the principal oil tract in West Galicia as about 14 miles long (E.—W.) by 1 mile broad, near New-Sandec; the others being some 40 miles further east, on the same strike. They appear to correspond more or less with the menilite zone (middle eocene), so called from the frequent nodules of menilite (a semi-opal). It is an undulating hill country, some 2,000 to 3,000 feet in elevation, forming a broad belt between the Carpathian axis and the alluvial land on the north-east. The rocks are massive sandstones with alternating sandy shales and marly clays, all steeply folded. The wells are from four to eleven fathoms deep, the sinking being continued as the oil gets exhausted and until the water becomes too troublesome, when it is found cheaper to open other shallow wells. In this way the wells are only from two to three fathoms apart. The Mikowka shaft is twenty-one fathoms deep; at six to seven fathoms it yielded about 4 cwt. of oil daily, but the quantity diminished as the shaft went deeper. There is no stratigraphical observation to account for this, but it may be presumed that the shaft passed into less oily beds. The Folinovka pit close by is also twenty-one fathoms deep, but yielded little oil, and further work was stopped by the influx of inflammable gases. The Ferdinand shaft at two fathoms got into grey shaly clay full of oil, but no flow took place till the water was reached, when the oil flowed freely. This occurred in several shafts, the oil increasing with the flow of water. In some places, for a square mile in extent, the whole ground seems saturated with oil; elsewhere gas and earth-wax (ozokerit) are the only signs of the oil, which probably exists at greater depths. Wells close to each other yield quite different quantities of oil, and that only for a certain time, when they have to be deepened. It is asked then, What would be the prospect of deep borings on the American system? Upon the supposition suggested by M. Foetterle, that the oil is produced near the surface, there would be none. But Dr. Hochstetter remarks that he found neither bituminous shales nor pyrites in any abundance; the beds in which the oil appears are sandy and earthy shales poor in "bituminous matter," occurring in a definite narrow zone with a constant strike; and he agrees with M. Foetterle as to the horizon of that zone; yet he goes on to say that he considers these rocks to have nothing to do with the oil otherwise than as vehicles; that the oil is not indigenous in these beds through which it reaches the surface, but is the product of the destructive distillation of organic matter at great depths, in coal-measures or other rocks that may be supposed to underlie the Carpathian sandstones. He indicates vaguely the difference of stratigraphical conditions here and in Pennsylvania where the oil-beds are struck at definite horizons, whereas in Galicia it is declared that the only chance of abundant oil is by tapping one of the more or less vertical deep-seated fissures through which it rises to be diffused in the crushed strata near the surface where it is now slowly extracted. Here, as in other fields, it is found that the lighter oil comes from the greater depth. Dr. Hochstetter's view seems like a hasty recoil from the superficial origin suggested by M. Foetterle, and a too ready extension of that assigned by M. Posepny (to whom he refers) for oil found in certain newer beds in East Galicia, connected with the great folding and fissuring to which all the strata have been subjected. He regrets that

[1] Jahrbuch d. k.k. Geol. Reichanstalt, Vol. XI (1865), p. 199.

no facts are available to test his views, for as yet (1865) no boring in East or West Galicia has exceeded 500 feet, while it would require numerous deep borings to arrive at any conclusion.

26. The oil-measures are much more productive in East Galicia, and an excellent sketch of them was given in 1865 by M. F. Prosepny.[1] He distinctly considers the oil to be indigenous in the bituminous shales with remains of fishes and the bituminous muds with fucoid remains occurring in the menilite group. In the later official geological map (1871) this group is distinguished as the *Amphysilen* zone, from the abundant remains of the small fish of that name; these rocks are also sometimes referred to as the fucoidal beds of the Carpathian series M. Posepny considers that the evolution of the petroleum in these beds was encouraged by the great dislocations and crushing they have undergone giving access to decomposing agents (not mentioned): and the same fracturing has permitted the oil subsequently to find its way into contiguous older and newer rocks. The very abundant sources in the soft miocene sandstone at Borislaw are taken to be supplied in this way. The workings are described as of the most primitive and wasteful kind:[2] shallow pits (seldom over 20 fathoms) at a few feet apart, to the number of 5,000, new and old, within a small area. While in work a shaft yields from 5 to 80 cubic feet daily.

27. A much more exact study of the petroleum rocks of Galicia has more recently been given by Mr C M Paul, of the Austrian Geological Survey.[3] His arrangement of the Carpathian rock-series would seem to involve considerable changes in the official map of 1871. The following groups are indicated:—

6 The neogene salt marl (lower miocene).
5. The Magura and Kliwa sandstone.
4. The Menilitschiefer.
3. The eocene Carpathian sandstone.
2. The middle Carpathian sandstone.
1. The Ropiankaschiefer or lower Carpathian sandstone (neocomian).

Of these, Nos. 1, 3, 4 and 6 are oil-producing; but of course only in certain bands, which locally may be some metres in thickness. The oil mostly occurs in soft sandstone although no doubt originally derived from the associated shales abounding in organic remains. Mr. Paul has no doubt whatever that the oil was indigenous in these latter beds, any connection of oil-rock with faulting and fissuring of the strata being only incidental. Thus, in these rocks too the oil is not original in the beds in which it actually occurs most abundantly. Here again it has been observed that oil appears most frequently along anticlinal axes, but Mr. Paul very sensibly connects this with the better exposure of the beds in this position, and does not at all infer the absence of oil in the synclinal folds whenever they can be got at. Actually vertical strata offer the least favourable condition. His remark that in the few places where the oil-bearing rocks are little disturbed they have not proved productive, would perhaps need further elucidation; for if a general rule, it would certainly imply that the squeezing, with evolution of heat, elsewhere

[1] Jahrbuch d. k.k. Geol. Reichanstalt, Vol. XV, p. 351.
[2] M. Posepny's figured section is as primitive as the native mining he describes.
[3] Jahrbuch d. k. k. Geol. Reichsanstalt, Vol. XXXI (1881), pp. 131-168.

experienced had been an effective cause in the accumulation, if not in the production of the oil; the latter would be an instance of "pressure metamorphism," as compared with the regional metamorphism of the same kind appealed to by Mr. Carll. Under the foregoing conditions it is mentioned as obviously unwise, unless for purely experimental purposes, to put down a boring or well on the actual spot of a natural oil spring; the trial should be made at some distance, according to the amount and direction of the dip of the oil rock. I have reproduced in Plate II a number of figures from Mr. Paul's paper, they will serve to illustrate the structural conditions in such ground; they are diagrammatic (not to scale) and few particulars are given as to depths and yield. Of Mraznica (fig. 4) it is stated that pits 100 metres in depth had for ten years been yielding about 1,400 kilograms each weekly; while some had given ten times as much. Both figs. 4 and 6 represent isoclines,—flexures in which all the beds dip in the same direction; fig. 4 is on the up-curve side of the flexure, a folded anticlinal, in which the oldest beds appear in the axis of the denuded flexure; fig. 6 is on the down-curve side of the flexure, a folded synclinal, in which the newest beds are found at the axis of the denuded flexure. This latter is then an instance of productive measures in a synclinal; the Polana pits proved very productive. The Schodnica workings (fig. 9) are among the most prolific; the pits are about 160 metres deep.[1] For a time the Magdalen pit gave 80 cwts. per day, and became steady at 40 cwts. The Boryslaw mines (fig. 10) are in the newer rocks. They are the principal source of ozokerit. The area worked is about 1,950 metres long and 700 metres broad, in which some 12,000 pits have been sunk. Some 2,500 are now producing oil, and 935 are for earth-wax. The principal shafts are about 160 metres in depth. The production of earth-wax now is about 250,000 cwts. yearly. The output of oil used to be 200,000 cwts., but has fallen to 35,000 cwts.; the winning of the wax is so much more profitable.

INDIA.

The Punjab.

28. All the petroleum of India occurs in middle or lower tertiary rocks, as in Galicia and at Baku. Within or near the Rawalpindi district of the Punjab there are some 16 spots at which symptoms of petroleum occur. Some of these are very insignificant, the product being quoted in teaspoonsful; the best (at Gunda) yielded for six months an average of about 11 gallons a day from a boring only 75 feet deep. They are all described in Mr. Lyman's report. His attempt at a geological correlation of the rocks at these different localities is simply ridiculous; but that is of little practical importance for immediate purposes. His views upon petroleum itself are more serious: he seems to have practically held to the view that pretroleum is for ever confined to the bed in which its materials were deposited; a notion that is demonstrably erroneous for the greatest known oil sources; and to a very important extent so in other regions, as in Galicia. Upon an extra arbitrary exercise of this opinion he actually formulated

[1] From the term used,—"Grube"—I infer that the extraction is by pits, not bore-holes, especially as borings are sometimes mentioned; but no particulars are given.

a rule (*l. c.*, p. 8), that the limit of depth (in the bed) to be expected at any locality would be half the length of the outcrop along which any trace of petroleum could be found. It is likely that the indications given by Mr. Lyman for the exploration of these localities are affected by these peculiar views: that a rock in which an accidental exhibition of oil occurred may have been indicated in both directions as an oil bed. Still, the descriptions and the detailed plans in his report supply an excellent basis for further explorations, for he seems to have been a good surveyor. At first at least, exploration should be limited to the neighbourhood of these natural springs; if it should be proven that these are but a faint indication of oil-bearing rocks underground, it may be permissible to attempt places where no such indications occur. The fact that all these localities occur in about the same geological horizon strongly confirms the opinion that the oil lies in and about its original birth-place; see section fig. 3, pl. I; the oil occurs in the bands numbered 5 and 6.

Khátan.

29. The best local description of the oil-measures of this North-West region is that by Mr R. A. Townsend in his account of the Khátan field in the Mari hills of Baluchistan, where he has recently carried out some successful borings in spite of most trying obstacles, both underground and above it. His report is printed herewith. The identifications of fossils and of geological horizons may not be quite correct, but we have seen that this is almost irrelevant to the question. Not so however the theoretical considerations regarding the origin of the oil, for the process of search must be largely influenced thereby. The notion of any essential connection between petroleum and the salts and sulphurous products that so often accompany it, is now very generally abandoned, the association being only incidental, or at most concomitant. There may be deep-seated coal beneath all this ground—Mr. Oldham's suggestion of Gondwana coal-measures in Rajputana, at the eastern edge of this geological region, would be a direct hint at such a possibility—but there is really no excuse for looking afar for what seems to be in our hand: Mr. Townsend's own description is the most satisfying yet on record that the oil is indigenous in these eocene rocks, probably in the shales that are described as so densely charged with organic remains, although the associated fractured limestones have afforded in their crevices convenient receptacles for the oil. I certainly think that this view should be the one adopted for immediate operations. Upon it, the Khátan boring would seem to be at the base of the measures, and may be already below them. A more likely site would be on outcrop No. 25 of the section, though not necessarily on this actual line, better at a lower level and where the dip is lowest so as to cut as many beds as possible. These shales are described as themselves oil-bearing. The 'marine conglomerate,' the chief oil rock of Mr. Townsend's report is, I am pretty sure, the 'limestone breccia' described by Mr. Blanford in his sketch report on that region[1] as occurring so widely at or near the base of the lower eocene series. Specimens of it sent by Mr. Townsend certainly contained nummulites; and Khátan is coloured as eocene on Mr. Blanford's sketch map, though he was not

[1] Memoirs, Geol. Surv. Ind., Vol. XX, Pt. 2.

able to visit that particular ground. I have found, in descriptions of works in similar measures elsewhere, notice of the great practical difficulty mentioned by Mr. Townsend of keeping a straight hole in rocks that are much broken or disturbed; the cutter must be reflected laterally on striking a hard surface obliquely, and so be diverted from the plumb line. I imagine that this difficulty has had much to say to the practice in Galicia of sinking deep pits instead of borings, notwithstanding the special advantages of the latter in the extraction of petroleum. But for the remark quoted above from Mr. Paul, that the measures in Galicia are not so productive where little disturbed, and for the independent uncertainty of their occurring anywhere on the same horizon, one might recommend a splendid place for a speculative trial boring at the base of the Kirthar limestone near Rohri on the Indus. It will be tried some day.

Assam.

30. A brief notice of the petroleum springs in connection with the coal-fields in Upper Assam was published in 1865, in the Memoirs of the Survey, Vol. IV, Pt. 3, p. 29, with a recommendation that trial borings should be made. In 1866 a Calcutta firm obtained a license to explore the ground and commenced operations in November of that year. A short account of this enterprise was published in the Survey Records for 1874, Vol. VII, pt. 2, quoting also a distillation assay of the oil, as compared with that of Pennsylvania and Rangoon oils. The results of the Makum borings were all that could be desired: none of the holes were of considerable depth, apparently less than 200 feet, yet in some the oil spouted intermittently with a pressure of 30 lbs. to the inch, yielding as much as 3,500 gallons in 35 hours from a single pipe; the dimensions were not given. Notwithstanding this superabundant supply the enterprise broke down, owing to the difficulties of transport from so remote a site. A further notice of the Assam petroleum is given in Mr. Mallet's report on the Naga Hills coal-fields (Memoirs, Vol. XII, Pt. 2), with an enumeration of places where the oil appears naturally at the surface. An apparent connection of this petroleum with the coal occurring in its immediate vicinity is more marked than usual. Mr. Mallet mentions having in one instance seen oil oozing out of the coal itself. There is nothing, however, to confirm the idea of any real connection: this coal is still the most highly 'bituminous' coal in India. Thick soft sandstone is the prevailing rock, but blue clay is mentioned as occurring in the borings; all are much disturbed. The exact age of these rocks is uncertain; they are more likely middle than lower tertiary. There can scarcely be a doubt that the oil resources of this region are very great. At present most of the best ground is within the immense concession granted to the Assam Railways and Trading Company; but apparently the oil is neglected.[1]

Arakan.

31. The coast of Arakan, from Cheduba island northwards, exhibits an immense thickness of tertiary rocks, chiefly sandstones and shales, crushed to-

[1] I recently had occasion to apply to the Manager at Dibrugarh for a barrel of oil, but was informed that the Company scarcely got enough for their own uses.

gether in more or less vertical folds. The same rocks and features continue northwards through Chittagong and the Tipperah and Lushai hills into Cachar. They are separated from a like accumulation of deposits in the basin of the Irawadi by the Arakan Yoma (range), continued northwards into Manipur, composed entirely of sedimentary rocks, the oldest of which seems to be of triassic age, with some considerable masses of serpentinous eruptive rocks. South of Cheduba the coast line is weathered back to the axial rocks, ending at Cape Negrais. The region of the islands and the adjoining coast has long been remarkable for its numerous mud volcanoes, caused as elsewhere by the eruption of hydrocarbon gases, and also as usual petroleum occurs freely in the neighbourhood and has for long been extracted by the natives, supplying an export of as much as 40,000 gallons a year from Kyoukpyu. The oil is very light and pure, and can be burned in lamps without refining. An excellent description of this ground by Mr. Mallet, was published in the Records for 1878, Vol. XI, Pt. 2, giving particulars of the mode of occurrence of the petroleum. In 1877 European enterprise was attracted to this industry and very promising results were at once obtained: one of the first wells, only 30 feet deep with a boring continued 36 feet deeper, gave a flow into the well, yielding at first about 250 gallons a day. In 1879 more extensive works were undertaken by the Borongo Oil Company. They started work most energetically, with a large staff of skilled workers of all kinds; they set up two stills of 4,500-gallon and 9,000-gallon capacity; in 1883 they had 24 wells in work ranging from 500 to over 1,200 feet in depth; for a few weeks one well yielded 1,000 gallons daily, but the total amount of crude oil pumped from 10 wells during the whole year did not exceed 234,300 gallons, of which they refined 65,450 gallons and sold the rest in a crude state. In 1884 the Company had to suspend payment. In the official report[1] from which these facts are taken there is a naive remark that goes far to explain the whole calamity,—"As yet no one in the Kyoukpyu field has discovered oil-bearing strata of the type of the good American or of the Caspian field, and so far the business of oil-winning on a large scale has not been a success." No doubt the promoters of the enterprise, like the enthusiast alluded to in para. 21, reckoned on that sort of thing; it is the unfortunate mistake alluded to in para 4, yet an intelligent diagnosis of the ground should have warned against such an expectation. There are no doubt very large supplies of high class petroleum to be got from this region, but it must be won by suitable methods. In Mr. Carll's work on the Pennsylvania oil-fields he bitterly laments the irretrievable loss of information through the want of intelligent record of such costly experiments: of the many thousand borings put down in that region, not one record in fifty, if obtainable at all, was trustworthy. We may echo the same regret here; no doubt useful hints for future guidance might have been obtained by intelligent observation of the numerous borings in Arakan.

Burma.

32. 'Rangoon oil,' under some other name, was probably an object of industry in pre-historic times. For many years it has been a steady article

[1] Administration of British Burma during 1883-84, p. 31.

of trade at Rangoon. It almost all comes from Upper Burma and from the neighbourhood of Yenanchaung on the east side of the Irawadi about 60 miles above Thayetmyo. The greater part of the produce probably goes to Rangoon. In 1883-84 this part amounted to nearly 1,000,000 gallons, mostly taken by the Rangoon refinery, which produced 640,000 gallons of refined oil during the year. The oil is extracted in very primitive fashion, by wells ranging from 100 to 300 feet in depth according to position. Some wells yield as much as 200 gallons daily. Dr. Oldham when with the mission to Ava in 1855 observed that the measures consist of soft sandstones and shales of middle or lower tertiary age, considerably disturbed.[1] They are apparently less so than the oil-measures of Arakan. Oils of lighter quality are said to occur to the west of the river opposite Pagan and in the Chindwin valley. A notice of the small oil workings in Lower Burma was published in the Records of the Survey for 1870 (Vol. III, p. 72), and again in 1873, in Mr. Theobald's report on the geology of Pegu.[2] It is unquestionable that the oil resources of Burma admit of an indefinite extension of enterprise; yet the country still imports yearly about 2,000,000 gallons of kerosine oil from America. It is I think a safe prophecy that the oil-measures of Eastern India may be supplying half the world with light within a measurable time when the American oil-pools have run dry.

Report on the Petroleum Exploration at Khátan, *by* R.A. TOWNSEND, *Superintendent of Petroleum Explorations in Baluchistan* (Plate I, fig. 4).[3]

Roads.

The Road from Sibi to Khátan *viâ* Bioraji Hill passes nearly the whole distance over the fluviatile deposit which characterizes the plains of the Indus and no change is observable until the low sand hills are reached at Gazi, 24 miles east-by-south from Sibi.

These low hills continue with a gradual rise until the south side of Bioraji is reached; their composition is a coarse semi-compact sand, unfossiliferous, except an occasional vegetable marking, with a few ferruginous concretions. They contain thin plates of fibrous gypsum, which increase in number and thickness as Bioraj is approached, and all have a low dip, chiefly westward.

Eocene rocks.

At Bioraji a sudden change to eocene nummulitic rocks is noticeable, and there are not visible any signs of a gradual passage through miocene and pliocene, to fluviatile rocks, although no doubt the space between Gazi and Bioraji is occupied by miocene and pliocene formations. The strata on the south side of Bioraji are very much broken and faulted and dip at all angles between the horizontal and vertical; indeed some are thrown beyond the vertical, and their original lower has become their present upper surface.

[1] Appendix A of Colonel Yule's "Narrative of the Mission to the Court of Ava in 1855" reprinted, with other papers relating to the geology and minerals of Burma, by order of the Chief Commissioner in 1882.

[2] Mem. Geol. Surv. Ind. Vol. X, Pt. 2.

[3] See para. 29 of the preceding paper.

Approaching Khátan by way of Thali and the Chakar river valley the same conditions prevail until a halting-place, Chakar Tung, is reached, and here begin a series of low ferruginous coarse-grained sand hills with strong red colouring; these are also unfossiliferous except slight traces of vegetable markings and concretions; they are, I think, upper miocene. At Turkhand, a little beyond this, towards Khátan, eocene rocks are again abruptly encountered, coming in with long straight ranges from the north-west bordering the valley leading to Mandi, and here a disturbance has taken place, producing probably a rift, which joins 3 miles further on with a deep synclinal which continues to and beyond the intersecting Sart valley, the latter passing through Khátan. At and near Turkhand the disturbance has been great and the contortions and foldings of the strata are surprising. The synclinal and rift form the water-course of the Chukar river. The fossils found thus far, differ in no way from those found at Khátan and need not here be considered.

Synclinal.

Entering the Sart valley the outer range on the right begins with a low out-cropping of nummulitic limestone dipping to the north at an angle of 60°. Bands of earthy shale containing *Cardita* are inter-stratified with the limestones, and the latter are composed chiefly of sub-angular fragments varying in size from an inch to two feet in diameter; several of these strata show a thickness of from 3′ to 20′; a few hundred yards behind these is the range proper, the top of which is composed of nummulitic limestone, rising from the synclinal in broken curves, it continues on to the south-west, gradually increasing in height until the highest point is reached at the Maurani peak, 4,800′ above sea-level. The axis of the range traced thus far, a distance of about 5 miles, is that of a gentle curve to the south-west with the concave side facing the Khátan river, the dip decreasing uniformly from 60° to 25°, and from north to nearly west at Maurani. A little to the south of the peak what appears to be a distinct and separate range intersects the Maurani ridge very obliquely; but on examination it is found to be a continuation of the original range produced by a faulting of the latter; it continues to bend to the south and east in irregular heights to beyond the Bioraji pass, and finally sinks down to the synclinal already named. It will thus be seen that the axis of the whole range describes an elliptical, or a rather horse-shoe form, enclosing the Khátan valley.

Sart valley.

Axis of range.

From the fault on to Bioraji, the rocks are thrown into a great variety of positions, vertical, and at every conceivable angle. Beyond Bioraji the dip again becomes fairly regular and is always at right angles to the axis, outward.

On the lower reaches of the river, the rocks are composed of angular clunchy limestone in alternating layers, each about 15′ thick, and between which are beds of earthy shales varying from 3′ to 12′ in thickness; all these strata are standing at a dip of 60° towards the north, but to the south-westward they gradually fall to about 25°; none of them reach the crest of the ridge, having been removed by denudation.

Lying conformably on the outer stratum of these clunchy limestones (see section, plate I, fig. 4) is a seam of brown coal or lignite about 20″ thick, above and below which are a few inches

Lignite.

of what appears to be volcanic ash of sub-aerial deposit, within this seam are occasional concretions of ironstone, very hard and containing iron pyrites, and Turritella, &c. The coal or lignite is of no value as a fuel, as it contains so large a percentage of sulphur and its compounds as to make it unsuited for contact with iron furnaces or boilers. The deposit is small and erratic, appearing occasionally further south-west in the outer range in thin ashy plates with dark carbonised markings.

Marine conglomerate.

A little further up the river bed on the left appears for the first time what I have considered to be a conglomerate of marine origin on the surface of which are patches, the remains of a fine-grained dark blue shale-like limestone, which where exposed becomes prominent because of its double jointed structure producing angular blocks, the whole resembling a ruined fortification. This and the conglomerate are the only rocks exposed over the surface of the inner mountain, all original superincumbent rocks having disappeared by weathering and denudation.

Inner cone.

The longest diameter of the inner mountain corresponds to a line passing through its centre nearly east and west, and such a line also divides the mountain into two equal parts, one with its strata dipping pretty constantly to the north, and those of the other to the south—in fact, it is a gently folded cone, around the base of which the river takes its course from the eastward, the valley embracing the space between this and the inner base of the outer range.

Crater appearance.

From an elevated position the whole presents the appearance of a volcanic crater with a cone in its centre, but only in appearance, as not a trace of true volcanic origin is discoverable.

Transverse section.

A transverse section of the range, valley, and a portion of the cone is shown in fig. 4. This section is made to bisect the maidan (plain or terrace) on which are located two borings for petroleum, and is fairly representative of the character of the whole range.

Beginning at the top of the range shown in section, we find a prominent and heavy stratum of nummulitic limestone, about 300′ thick at this point, marked Nos. 1, 2, 3, 4. No. 1 is massive of slightly yellow colour and is rather porous although very firm; it is uncrystallized and abounds in nummulites, nautili and other molluscs and radiates. Strata 2, 3 and 4, also nummulitic, differ from No. 1 only in colour and texture, 2 being massive, of a pale yellow colour, and hard and clunchy in structure. No. 3 is identical with No. 1. No. 4 is very white, rather soft and chalky; all contain nummulites and break with a fracture vertical to their line of bedding in planes, not unlike basalt. Nos. 5, 7, 9, 11, 13 and 15 are all strong beds of light brown earthy limestone, and between them are numerous bands of thin limestone from 1 inch to 1 foot thick, with thin clay and shale bands; all these are covered with debris and can only be examined in one or two places, but judging from their broken fragments they are all sub-divisions of the nummulitic series. No. 6 is a curious combination of angular blocks of white limestone. No. 8 is a heavy seam of very pure white gypsum in many places 15′ in thickness, extending throughout the whole length of the range. In many places very beautiful markings of pink colour are found, caused no doubt by iron oxide

in a state of solution. No. 10 is another heavy band of grey gypsum, in all respects like No. 8, except in colour and co-extensive with it. No. 12 is also gypsum, but is a thinner deposit, being only about 3′ in thickness and less pure than the others; all are unfossiliferous and are beautifully exposed in many places. No. 8, being massive, it is quite possible that blocks sufficiently large for artistic purposes could be obtained from it. Between Nos. 15 and 16 there is a trace of lignite with volcanic ash which appears in an erratic manner on the top of No. 16. Immediately above the lignite is a deposit of very friable coarse shale, weathering into mud if wet, teeming with echinoderms and small Cardita. Nos. 16, 18, 20, 22, 24 are all continuations of the clunchy limestones mentioned as appearing on the lower reaches of the river; and Nos. 17, 19, 21, 23 correspond to the earthy shales between them, but here they have lost their earthy character and are very beautifully coloured soft shales, with, in places, enormous quantities of fragile carbonized nummulites which crumble at a touch. No. 25 is a thick deposit of silky olive shales with numerous concretions of vegetable origin; the majority of them are soft and contain often pieces of carbonized wood in good preservation No. 26 is a band of dark brown flint which here appears for the first time; it is not uniform in deposition, many breaks occurring, but it can be traced for miles always in the same relative position, that is, between Nos. 25 and 27. The latter is also a soft olive shale differing only from 25 in having singular and large masses which have become indurated, and which have a slaty cleavage and are highly carbonaceous. It is in these two deposits of shale that the first traces of petroleum are discovered and in several places where vertical faces are exposed to the direct sun's rays, bituminous drops and threads mark them with a jet blackness. Beyond the concretions named I have not discovered any fossils in these shales. No. 28 is another band of flint of very dark colour of about 1 foot thickness, and is I think throughout composed of sponge spicules; in many places the original sponge form is retained, but so cracked are they that it is difficult to remove one in a perfect condition.

Wherever this band appears among the low shale hills on the terraces at Siah Kuch or elsewhere in the valley splendid specimens of fossil sponges abound, all rather large for transport. Besides flints thin plates of fibrous gypsum from ½″ to 1½″ in thickness occur; they are very hard and of dark brown colour, and are scattered through the shales last mentioned and appear to have been formed from waters holding in solution sulphate of lime in their passage through openings caused, no doubt, by slipping; these plates give a metallic sound when struck together. Nos. 29—31 are similar to 27, and No. 30 is a repetition of 28.

Rocks conformable.

Thus far all the rocks exposed are lying conformably upon each other, and all may be said to contain nummulitic fossils, except the last shales (No. 31) and the flints; a total thickness of about 4,600′ is exposed, vertical to the line of bedding.

Inner hill.

Having crossed the river bed we enter on rocks quite different from any so far described. No. 32 is a fine-grained hard blue limestone in divisional planes of various thickness from 3″ or 4″ to 2′, and jointed in structure by straight parallel planes of fracture vertical to plane of bedding and crossing each other at various angles. Some of the

blocks thus produced are singularly uniform in their dimensions and wonderfully straight and smooth on their surfaces; as before stated, these resemble a masonry wall. Very few fossils are found in them, concretions resembling turtles in form when extracted, some vegetable markings and one ammonite, are all I have found.

Cretaceous rocks.

The ammonite is but a sorry specimen, very much flattened and outlines destroyed by pressure, but it is plainly an ammonite, and from it and the character of the succeeding rocks, No. 33, I am inclined to believe that all the inner mountain exposures from this point are cretaceous, and not, I think, of tertiary age.

Faults.

At almost regular intervals the whole of this marine conglomerate covering the inner hill is faulted to the west, the exposed face at each fault being vertical and of considerable height (in one instance over 100'); "slickensides" are numerous, and it is probably because of faulting that the shales No. 31 appear to lie unconformably upon it; as a conglomerate it is peculiar, angular pieces of very hard dark limestone and flints are embedded in a matrix which is evidently the ooze of a not very deep sea, and which has circulated among sponges and angular pieces, embracing them in so firm a grip after hardening that a good blow will fracture both matrix and its enclosures in a straight plane without deviation. It is highly fossiliferous, orbitula and other foraminifera appearing.

Sulphur springs.

A little below the cross-section line are several copious springs of sulphurous waters, which have a temperature of 109° F. at the point of overflow; considerable quantities of sulphur crystals occur in the stalagmite surrounding them. No doubt quantities of native sulphur exist in the rocks below, and very probably the supply of water is obtained by the river losing itself at a higher point of its course, and following a fault which appears near the springs. Further up the hillside are many places where similar springs have accumulated stalagmite with sulphur intermingled in past time.

Petroleum.

Petroleum is found exuding close to the sulphur springs and for a considerable distance up the valley; along the edge of the marine conglomerate there are beds of bituminous deposit (petroleum mingled with gravel and earth) often 15' in depth, while up the hillsides for 200' the debris resting on the conglomerate is blackened by old flowings when the river bed corresponded to their levels. The hard compact nature of this conglomerate prevents the river from denuding it, hence the shales next above receive the wasting contact of the river torrent, and thus a continuous lower level is being annually made along the edge of the conglomerate, and the sulphur waters and petroleum naturally seek the lowest and easiest point of exit; this, no doubt, accounts for the old markings referred to.

Besides these bituminous deposits there are in many of the vertical crevices, over a large area, included plates and particles of petroleum which from long exposure have lost their volatile components and have become solid and much like ozokerit in character and appearance.

Crystals.

Within these crevices (and they are abundant) selenite crystals often contain small globules of both solid and liquid petroleum. The slow rate of denudation occurring in this almost rainless district,

when considered with the height at which old flowings are found (200′ above present natural flowings), together with the time required for the formation of natural crystals, dimly indicates how long petroleum has been escaping to the surface in this locality. Its rapid disappearance after escapes is owing to its great specific gravity, and to the readiness with which it is converted into a solid easily ground and mingled with the gravels of the river below.

Borings.

There are three trial borings for petroleum, one of which is 524′ deep, of 4½″ diameter. In the deepest of two of these borings (the other is but a shallow one), the following, in order of succession downwards, are the rocks penetrated:—

	Thickness.	Depth.
(1) Gravel, with boulders and bitumen	12	12
(2) Jointed blue limestone	20	32
(3) Hard marine conglomerate with abundance of flint	195	227
(4) Alternating bands of soft bluish shales and hard flinty limestone with iron pyrites.	30	257
(5) Rather hard shales with pyrites	217	474
(6) Dark grey limestone without fossils	2	476
(7) Soft grey shales	48	524

Oil was obtained at 28′, at 62′, at 92′, at 115′, at 125′, at 133′ and at 374′.

Rocks creviced.

The conglomerate is broken and fractured in all directions, and through these the oil finds its way upwards, borne on the top of the warm waters which accompany it, but while these fractures afford a ready means to the miner of "striking oil" they sadly interfere with his progress in boring, as the drilling tool in descending must inevitably enter many of these crevices at an acute angle to their planes, and it is almost impossible to prevent the tendency of the tool to follow the vagaries of such crevices and thus produce a "crooked hole," which is fatal to further progress unless straightened. It is, all round, the most difficult of rocks in which to construct borings the writer has yet encountered.

Character of the oil.

A report of the character of the petroleum obtained here has, in 1884, been sent into the Government of India, and I need only add that owing to infinitesimal particles of sulphurous and acid waters being held in suspension within the oil, it is most difficult to distil it. These particles in the process of distillation are vapourized at a little over 212° F., while the oil vapourizes at over 306° F.; the consequence is the vapour first created causes the oil to foam within the still, and finally carries it over with it into the condensing pipes bodily, which operation is known to refiners by the inelegant term "puking." The remedy lies in a specially constructed still, or a

mechanical appliance in ordinary stills for beating down the foam, or by a chemical process for removing the waters before distilling is undertaken.

At present about 1,000 barrels of crude oil are being sent to Sibi, for a thorough test as to its suitability for locomotive fuel.

Gas.

Both in drilling and pumping the borings, a considerable quantity of sulphuretted hydrogen gas is evolved, but it is not in sufficient quantities to cause a natural flow of oil from the tubes. In pumping the oil from the show obtained at 374′ we found that it came up with the warm water in very small globules, thoroughly mingled with and giving the water the appearance of having had snuff thrown into it; at rest the oil and water soon separate and the water becomes clear.

Theory.

It has occurred to me as a tenable theory that the petroleum of this locality may be produced by the action of sulphurous acid waters combined with alkalies, all at a moderately high degree of heat acting chemically upon a deep deposit of coal, or lignite, under confinement, and it may be that all petroleum has a similar origin. It is a fact that all producing oil-fields are in strata containing sulphur, salts and alkalies. The Canadian and American fields both retain inexhaustible supplies of saline sulphurous waters, some of them sufficiently strong to destroy in a few weeks the iron tubing used in pumping.

Economic rocks.

Besides petroleum there are no products of economic value here. If works were established for the manufacture of oil it is possible that saltpetre, alum, and alkalies might be produced at a profit from the manipulation of the shales. Of gypsum there are endless quantities of excellent quality, but too far from any market, I fancy, to export at a profit. The entire country round about is barren, save a few tamarisk and other scrubby trees, and a few acres of cultivable land. All the waters available for domestic use are charged with sulphate of lime and do not conduce to one's health.

Boring Exploration *in the* Chhattisgarh Coal-fields, *by* WILLIAM KING, B.A., D.Sc., *Superintendent, Geological Survey of India.* (With map and plate.)

1. RAMPUR COAL-FIELD.	2. WESTERN FIELDS.
A. Lillari Valley.	A. Mand Valley.
B. Oira Valley.	B. Korba.
C. Baisandar Valley.	
D. Pazar Valley.	

1. RAMPUR COAL-FIELD.

The name Rampur Coal-field was adopted by the Central Provinces Government for convenience; but the borings have as a matter of fact been put down at likely places on three sides of the area originally described[1] by Mr. V. Ball as

[1] Rec. G. S. of I., IV, p. 101; and VIII, p. 102.

the Raigarh and Hingir Coal-field, or partly in the Sambalpur District, and partly in the Gangpur State of Chota Nagpur. My own connection with the field began with the season 1883-84, when boring sites were selected:[1] and the mechanical work has been carried out since then by Mr. T. G. Stewart, the Assistant Mining Engineer, whose boring journals are given in the appendix to this paper.

The samples of coal so obtained have unfortunately been always more or less poor; and as there is no fair indication of any possible improvement in other parts of the field, I am reluctantly compelled to recommend its abandonment.

At the end of the season 1884-85, I reported[2] the general results of the exploration up to date in the Lillari Valley section, and they were poor enough. The existence of an upper though useless band of coal seams within a moderate depth and convenient to the proposed Hingir Road railway station had been ascertained; but as there still remained a considerable southward area of yet lower coal-measures with exposures of coal lower down the same valley and likewise not too far from the railway trace, it was decided to prove them by further borings at the commencement of the ensuing season (1885-86) before moving the plant to new ground. No better coals were found, although, I think, almost the whole thickness, and all the seams of the Barakars on this the southern side of the Hingir plateau were proved.

A. Lillari Valley.—Six borings were put down with more or less success over about a square mile in the neighbourhood of Chowdibahal during the first season; and four more, respectively near Kaliabahal Bonjari and Ghanamal, one being between the last two villages, later on: ten in all, of which however it is only necessary here to refer more particularly to seven, *viz.* Nos 1, 2a, 3, 5, 6, 7, and 8 (see plate). The sites of these are also indicated by the same numbers on the Sketch Map, as lying along the right bank of the river. Nos. 1, 2a, and 3 are at the corners of a triangular area, one side of which (1 to 2a) forms a line with Nos. 5, 6, 7, and 8 at right angles to the strike of the beds, or, taken in this order of numbers, against the dip which is generally very low to the north-northwestward; that is, No. 2a is in the uppermost and No. 8 in the lowest band of carbonaceous shales and coal seams of the coal-measures.

The difficulty in considering this set of bore sections is as to the recognition of seams of coal or other strata in two or more of them; for, as a reference to the appendix or the plate will show, there is considerable variation in the thickness of the coal seams and in the constitution of the beds associated with them. Fairly well defined strata, such as the hard band of compact red clay-stone (*x* in plate) belonging to the overlying Kamthis, are however recognizable in bore holes 1, 2a, and 3; while there can hardly be a doubt as to the continuity of the tolerably similarly constituted band of carbonaceous shales and sandstones below, and the coal seam (*a*). The dip of this coal seam if it be even is very low; in fact, rather lower than the average I had calculated on in my first

[1] Rec. G. S. of I., XVII, p. 123.
[2] Rec. G. S. of I., XVIII, p. 196.

report. The real condition appears to be that the beds roll somewhat, while they are often almost flat, and are only occasionally at so much as 10° to 15°.

Reckoning on this generally low dip, and knowing how necessary it was to try and get at good coal as quickly as possible, I ventured on taking the next borings at long intervals. The result tends, I think, to show that each of the holes along the main line has passed through at least one of the seams of shale and coal met with in the preceding bore. Thus, No. 1 has passed through coal met with in 2a and 3, and penetrated yet lower strata with coal; No. 5 has proved strata occurring in 1, 2a, and 3, and reached yet lower measures; while No. 6 encountered the lowest beds in No. 5, and touched others considerably below them.

I have always had my doubts as to the regular behaviour of the bedding in the interval between Nos. 6 and 8; having been led from indications on either side of the country to surmise that there might be here a roll up from the normal low northerly dip. Thus it is difficult to be confident about the connection or continuity of the carbonaceous shale bands with coal in Nos. 6, 7, and 8; but the presence of an intervening band of more decidedly sandy strata, recognizable in each section, leads to the conclusion that the shales and coal below them belong to the same horizon.

On this recognition, or connection, of strata in the several bore-holes, and taking No. 6 as having reached the lowest coal-bearing beds in its position, I calculate that these borings have pierced through an aggregate thickness of 480 feet, which is not far off my original estimate.[1]

The upper or Chowdibahal portion of the Lillari Valley has been treated of in my previous paper;[2] and there is now little use in repeating more than that in the 220 feet or so of ascertained coal-measures, there are two permanent seams of 6 to 7 feet in thickness, another which appears to merge into a more shaly seam, and some smaller seams of a foot or so in thickness. All the coal is bad; the average percentage of ash in them being 36·09, except in one case where it runs as low as 22·92 in the 4th foot of a 6-foot seam at 69 feet from surface in bore-hole No. 4.

An outcrop of coal, of which I had ascertained at least a thickness of 4½ feet, occurs about half a mile lower down the river, to the north-east of Kaliabahal; and I thought it might be perhaps the edge of seam (*b*) in the Chowdibahal holes. Hole No. 5 was put down a short distance to the north of the exposure and struck a 9-foot seam of coal at 37 feet, which at first sight looks very much as if it were after all an outcrop of the seam (*a*) in No. 1. This may really be the condition of affairs; but I am inclined to doubt it, mainly indeed on the extremely low and almost southerly dip involved in such a relation, and the want of correspondence in the beds below as displayed in the further progress of the boring, but partly on account of the nearer correspondence of the assays of this coal with that of (*b*) in No. 1.

[1] Rec. G. S. of I., XVII, p. 129.
[2] *Op. cit.*, p. 196.

ASSAY. (Foot by foot.)

Bore-hole No. 5, 37 feet from surface, seam (? b), 9 feet thick.

	1	2	3	4	5	6	7	8	9	Average of 1—9.
Moisture . . .	7·08	8·28	8·56	9·20	8·94	7 96	8 42	6·88	8·48	8·20
Volatile matter (exclusive of moisture) .	21·88	22 40	23·18	22·32	21·80	23 28	21·86	21·28	21·92	22·21
Fixed carbon . .	25 72	27 42	30 08	28 60	28·42	20·84	23·44	17·88	24·02	25·16
Ash	45 32	41 90	38 18	39 88	40 84	47 92	46 28	53 96	45 58	44 43
	100 00	100 00	100 00	100 00	100·00	100·00	100·00	100·00	100·00	100·00
	Do not cake. Ash grey and reddish grey.									

Assay of 8-feet seam (b) in bore-hole No. 1 at 142 feet from surface, for comparison with the above.

	$\frac{142}{1}$	$\frac{142}{2}$	$\frac{142}{3}$	$\frac{142}{4}$	$\frac{142}{5}$	$\frac{142}{6}$	$\frac{142}{7}$	$\frac{142}{8}$	A well mixed sample of Nos. $\frac{142}{1-8}$.
Moisture	11·08	10 58	12 00	11·02	9 40	7·44	8·04	13·38	9·98
Volatile matter (exclusive of moisture)	22 14	21·26	22 66	22·06	20·52	19 00	18·60	23·84	21·22
Fixed carbon	27 08	25 70	28·36	26·42	24 04	19·48	20·32	32·90	24·62
Ash	39·70	42 46	36 98	40 50	46 04	54·08	53·04	29·88	44·18
	100 00	100·00	100 00	100 00	100·00	100·00	100·00	100·00	100·00
	Do not cake. Ash grey and yellowish grey.								

The coal is bad, even inferior to that in seam (*a*) of the Chowdibahal ground. This bore-hole was run down to 221 feet, disclosing further seams, two of which are over 15 feet in thickness. They tell the same tale of poorness of quality; in fact, the lower thick seam consists of such worthless stuff that we did not consider it worth sending down to Calcutta for assay. Two of the samples

sent down from the upper 15-feet seam got mislaid in despatch, but their quality was on a par with the rest which are given in the following assay :—

Bore-hole No. 5, 114 feet from surface, 15 feet thick.

						6	7		10	11	12	13	14	15
Moisture .	7·64	8 08	8 36	8 20	9·20	7·36	7·44	7·28	Mislaid, but of the same style.	8·50	8·76	9 86	8·46	9·92
Volatile matter (exclusive of moisture) .	26·18	25·34	24·38	23·36	26·60	21·82		22·80		23·72	23 94	23·98	24·92	25·46
Fixed carbon	29 08	29 60	27 30	25·74	29·72	23 06	21 28	23 26		26 24	27·40	29 02	28 50	33 64
Ash . .	37 10	36 98	39·96	42 70	34·48	48 76	49·72	46·66		41·64	39 00	37·14	38·12	30 98
	100·00	100 00	100·00	10·000	100·00	100·00	100·00	100·00		100·00	100 00	100·00	100 00	100 00
	Does not cake, ash light.									Reddish grey.				

The results so far certainly tended to crush any hope of our striking better coal in this division of the field; and had it not been that proximity to the railway line demanded the trial of every reasonable chance, I should have preferred abandoning the work at this point. As it was, warning was given to prepare for a move, pending the hazarding of three more holes on the same line, No. 6 near Bonjari, No. 7 a mile further down the right bank of the river, and No. 8 near Ghanamal. The only coal of the different seams struck in these holes which appeared worth sending down to Calcutta gave this assay:—

Bore-hole No. 6, seam 7 feet thick at 62 feet from surface.

	1	2	3	4	5	6	7	Average of 1—7
Moisture . . .	7·34	6·20	6·16	5·74	5·80	6·54	7·28	6·44
Volatile matter (exclusive of moisture).	26·06	24·56	24·56	23·94	24·38	26·06	25·62	25·03
Fixed carbon . .	31·04	27·80	28 38	27 46	27·64	30·84	31·40	29·22
Ash	35·56	41·44	40·90	42·86	42·18	36·56	35·70	39·31
	100·00	100·00	100·00	100·00	100·00	100·00	100·00	100·00
	Does not cake. Ash, reddish grey.							

There was clearly no use in holding out any longer at the Lillati Valley, so a move was made for what I had already described in my report on the selection of boring sites as the next more promising part of the field, the Oira Valley section, where two seams of coal are exposed at times—according to the scour—in the bed of the river near Dibdorah, one of the villages in the small zemindari of Kodibuga.

In the meantime, it was intimated to me that the Minister for Public Works had suggested that the Baisandar Valley on the north-easterly edge of the Hingir plateau seemed, from the numerous exposures of coal, to offer better inducements for boring with any hope of success. In the original paper by Mr. Ball, there is no

particular expression of the promise of these outcrops; in fact, he does not hold out much prospect of good coal. I too had learned sufficient of that side of the country to infer that these many outcrops would most likely turn out to be repetitions of one or two seams through their coming to surface in the windings of the Baisandar and its tributary the Jhajia nala as they flow for some distance along the strike of the strata. The look-out was therefore really no better, if indeed as good as that at Dibdorah; and, after all in moving the plant round by the Dibdorah side of the field, there was not much time lost in the transit, while even in case of disappointment, there would be the satisfaction of having proved the condition of that side of the country. The move was therefore made to Dibdorah.

B. Oira Valley.—In this part of the field, I had myself in 1884 cut down into 12 feet of the coal outcrop on the very edge of the coal-measures and with the fuel so raised a big camp-fire was kept going every night; only, there were always big lumps of partially consumed shale remaining with a great heap of ash in the morning. The coal itself was in thin bands with more or less intervening shale; but it seemed to me that about 4 feet of the seam dug out so far might be taken as fair coal, and I hoped that improvement might be disclosed by boring. The objection to the place lay in its comparatively difficult approach from the line of railway, the Dibdorah measures being in a very narrow and enclosed valley below and on one side of the Hingir plateau.

Two borings were put down near Dibdorah at about 800 feet apart and nearly with the line of dip; No. 1 was carried down 215 feet, and No. 2, close to outcrop already mentioned, to 131 feet. The work occupied a month, and was about as dismal an operation as could be watched from day to day with the weary drawing up of the usual disappointing carbonaceous shales and sandstones; and when the coal was struck the most of it was hardly worthy of the name. There was really little use in sending the samples down to Calcutta for assay, and I got Mr. Stewart to make rough experiments in a small iron cup by which we used to ascertain from 30 to 40 per cent. of ash, or perhaps a foot of somewhat better stuff was brought up at intervals which yielded from 17 to 20 per cent. We did however send samples from hole No. 2, that is from the seam giving the outcrop whence I had extracted and burned coal: and here is the result:—

Oira Valley, Dibdorah boring No. 2, 14-feet seam, 47 feet from surface.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	Average 1—14.
Moisture .	5·44	4·54	4·96	6·84	4 48	3·54	4 40	4·44	6 02	5 62	5·56	6 40	6·80	6 66	5 41
Volatile matter, exclusive of moisture . .	28·58	22 12	240	17·16	25 06	22·46	24 00	22 12	23·34	21 50	22 20	23 42	23·28	25 28	23 06
Fixed carbon	35·08	29 48	1·70	22 28	30·16	24 12	29·62	27 98	28 96	25 30	26 06	29 14	30·22	33 36	28 82
Ash . .	30·90	43 86	0 94	53 72	40·30	49 88	41 98	45 46	41 68	47 58	46 18	41 04	39 70	34 70	42 71
	100·00	100 00	100·00	100 00	100 00	100 00	100 00	100 00	100·00	100 00	100 00	100 00	100 00	100 00	100 00
	Does not cake Ash, light reddish grey, slightly varying in shade.														

The whole plant was not however kept at work on these two borings alone; for another boring was being tried and looked after about 8 miles to the northward close to the railway line near the village of Birapali, where I tried to get through the Kamthis, nearly always a troublesome matter owing to the hard nature of the sandstones and their frequent conglomeratic constitution. The rocks were very hard: it took 11 days to get down through the last 20 feet; and as the season was getting on, and the Baisandar field must be tried as a last resource, orders were given to stop work on this side of the country.

O. Baisandar Valley.—The transit across the Hingir plateau was made with considerable difficulty; but, leaving Dibdorah on the 26th February, borings were in progress in the neighbourhood of Jhaprunga by the 8th March. There was not much time for trial between this and the end of the season (May 1st); the country was quite new to us, and considerable local difficulties in the way of labour and supplies had to be overcome, while the mining assistant was badly hampered by sickness himself, and sickness among his followers, one of whom (the foreman blacksmith) had died at Dibdorah. However, a great push was made and four holes (one supplementary on the breaking of a chisel in No. 2) were carried out at likely spots.

As on other sides of the plateau, except in the Lillari Valley, there is only a narrow belt of the Barakars or coal-measures exposed in the immediate river valley; the overlying Kamthis coming in along the southern side rather quickly and forming all the rather high flat-topped group of the Garjan (1,947 feet) hills. It would have taken too long to try the ground by a set of holes along the dip, as in the 2nd and 3rd of these I should have had most likely to get through Kamthis, which practically comes to very slow boring. The thing was to get an idea as to whether there was any good seam to work on; and I chose three sites along the strike, that is parallel with the Jhajia nala and the Baisandar after their junction, at sufficient intervals for any chance of improvement in the seams on their lateral extension. Sites for holes Nos. 1, 2, and 3 were selected respectively near Gopalpali, Ratansarai, and Bankibahal. The Ratansarai boring had to be abandoned owing to the breaking of a chisel short off at the shoulder, which could not be extricated; but the supplementary hole 2*a* sunk further to the south had not reached the coal seam by the close of the season. Indeed, the work could not have been carried on any longer; for by that time Mr. Stewart had to be carried in to Sambalpur for medical advice and treatment

A reference to the plate will show the rather varied character of the seams and associated strata: and I should have found it difficult to connect them had not the notes made by Mr. Ball of the river sections been on record.[1] In the bore-section No. 1 the upper coal seam with its great thickness of carbonaceous shales below and good thickness of similar shales and coal seams above, answers to the rather thicker outcrop in the natural exposure on the Tikripara ghat. The 25-foot seam at the bottom of the bore is on the other hand not represented in Mr. Ball's 168-foot section on the Baisandar-Jhajia junction (*op. cit.*, p. 103), though his long list of coal shales, paper coal, &c., near the bottom may be taken as a representative condition of it. Boring No. 2 struck coal at once almost (16 feet, seam *a*), but the thick sandstones and shales below it are not so easily brought into

[1] Rec. G. S. of I, IV, pp. 103-5.

connection with the shales below (*a*) in No. 1, until judged by the light of the following extract from Mr. Ball's paper:—

"In the bed of the Jhajia river westward the large seam becomes much broken up by interpolations of sandstones and shales, and with the dying out of the coaly bands the change is so complete that it is impossible to recognize it or trace any portion of it through successive reaches."

The seam referred to here is of shales, and it is just such a change as this which would tie in with the rather extreme variation displayed in the two bore-holes at either end of the area. The two lower seams of coal in hole No. 2 would answer to the thick seam (*b*) in No. 1.

The strata and coal beds met with in bore-hole No. 3, with the exception of the upper coal, do not answer satisfactorily to those in 1 and 2, the hole being mostly in beds which are below, or lower than those in 1 and 2, the auger having almost immediately penetrated a thick coal seam answering to that in the bottom of No. 1. The sandstones at the bottom of the measures have evidently also thickened out a good deal in the direction of Bankibahal.

These borings have altogether pierced an aggregate thickness of about 300 feet of Barakars, and have proved the existence of four seams of coal. The coal is however no better than that found over the rest of the country; that from holes 1 and 3 was not worth assay, though no doubt there are occasional thin bands or layers of good quality separated unfortunately by thicker bands of shale. Rough assays in the field seldom gave less than 40 per cent. of ash; and similar trials of coal from the outcrops near Bankibahal, the Tikripara ghat, and to the north of the No. 1 or Gopalpali boring, confirmed these.

An exposure close to the Ratansarai or No. 2 hole was the other way; in fact somewhat after the manner of the outcrop I have already referred to at Dibdorah, in so far as it differed materially from the miserable stuff brought up from the bore-hole. The outcrop occurs in a small ravine a short distance north of Ratansarai, and Mr. Stewart cleared away about five feet of the seam which is underlaid by a band of shale. There are thin layers of shale in this five feet, and one of iron pyrites; but four feet from which he took eight samples of each layer or band of coal, yielded the following rough assays —

No. 1.—Moisture	. . . . . .	8·00
	Ash (greyish white)	22 00
No. 2.—Moisture	. . . . . .	8 00
	Ash (greyish white) . .	32 00
No. 3.—Moisture	. . . . . .	10·00
	Ash (whitish red)	16 00
No 4.—Moisture	. . . . . .	10·00
	Ash (dark grey)	7·00
No. 5.—Moisture	. . . . . .	12 00
	Ash (greyish white)	6 00
No. 6.—Moisture	. . . . . .	5·00
	Ash (greyish white)	9 00
No. 7.—Moisture	. . . . . .	8 00
	Ash (whitish grey)	13·00
No. 8.—Moisture	. . . . .	8·00
	Ash (whitish grey)	15 00

Fair specimens from the same layers were sent to me, and have been tested in the laboratory.

Coal from outcrop near Ratansarai near bore-hole No. 2, Baisandar Valley.

4 feet

	1	2	3	4	5	6	7	8
Moisture	7·08	3·72	9·48	7·36	12·26	8·94	6·88	5·26
Volatile matter (exclusive of moisture) . . .	27·94	24·98	28·58	31·00	30·62	32·66	32·82	29·58
Fixed carbon . . .	42·48	29·20	38·12	43 08	50·60	46·32	41·62	37·32
Ash	22·50	42·10	23·82	18 56	6 52	12 08	18·68	27·84
	100 00	100 00	100·00	100·00	100 00	100·00	100·00	100·00
	Sinters slightly.			Cakes, but not strongly.				
	Ash, light-reddish grey, slightly varying in shade.							

Such a difference as this between coal at the outcrop and the samples from the bore-hole which Mr. Stewart did not think worth sending to Calcutta for assay is remarkable, though not much more remarkable than that between the Dibdorah exhibitions, and it certainly seems to throw some doubt on estimates made on boring samples. Indeed, Mr. Stewart tries to account for the difference by an inference that the coal from the bore-hole may often get mixed up with a good deal of shale fallen down from the sides of the hole, and that the lighter coal passes off in washing. Doubtless such a mixture may take place to some small extent, but I do not think appreciably so; the hole is always cleaned out foot by foot before the chisel is set to work on a fresh 12 inches of descent, while the lowering and drawing up of the sludge-pump must as a rule smooth off any asperities in the hole fairly well. Thus, the only shale that can ordinarily fall is such as might be knocked off in the descent of the chisel and rods for the next operation, and their withdrawal prior to sending down the sludge-pump for the new stuff. Experience in the Chanda, Rewah, and I think in nearly all cases where coal has been worked on our boring, has shown that the bore-assays give a fair estimate of the capabilities of the coal, from which even a slight reduction must be made to tally with the results exhibited on actual work.

It must also be noted that it is only the fragments of coal and coaly shale obtained from working of the material brought up which are assayed; it being more by practice and a knack of sampling and fingering that a boring expert can judge of whether the material can be considered a *coal* with more or less of shaly partings, or a *shale*-with more or less of coaly laminæ, or a *coal altogether*. I have full confidence in Mr. Stewart being an expert of this stamp, and an honest one too

As it is, all the boring sections which we have carried out agree fairly well in their exhibition of the poorness of the seams of coal such as it is, and I can only come to the conclusion that the outcrop near Ratansarai, as well as that near Dibdorah, is rather an evidence of local and rare occurrences of good coal than that the boring sections indicate local falling-off in the quality of the seams generally.

It would have been satisfactory had the supplementary boring No. 2a been carried down even through the seam already met with in No. 2, if only as a sort of check on its display of evident depreciation on the outcrop, but this could not be done; and were it not that the whole evidence is so much against any improvement, I would almost like to carry on that hole before removing the boring plant which is now stored at Jhaprunga.

In considering the operations which have now been carried out, it is to be noted that after all only three sides, except in the upper portion of the Lillari Valley, of this large area have been tested; a considerable portion remaining unexplored in the middle or upland of the Hingir plateau. In the first place, the most promising portions of these edges have been tested; while I am pretty certain from my examination of the outcrops on the north-eastern side, that is, in the Dulunga, or Godadia Valley, that there is no hope of more promising boring in that direction. The Lillari borings near Chowdibahal are only 4 or 5 miles from the Godadia Valley, the interval being covered up by Kamthis; it is extremely unlikely that there should be any improvement in that interval other than perhaps locally and of insufficient extent for railway requirement. There is a further place of coal outcrops between the Lillari and Oira Valley sections, namely, that of Lakanpur or the Bagdia Valley, where denudation of the overlying Kamthis has given a bay or broad indentation displaying a good many of the beds and some of the seams already met with on the Lillari and on the Oira. I have examined the Lakanpur outcrops, and they are just of the character now so well known all round the country.

There remains a long strip of Barakars, showing however no coal, on the south-western side and in the neighbourhood of Hingir which might be tested; but I have no ground to go on, not even the lingering chance that here there should be for once in a way a richer part of the field than anywhere else. It will be seen presently from my account of the Pazar area of Barakars, some 8 or 10 miles to the north, that my abandonment of this Hingir tract is not due merely to opinion and despondency. Next, as for the upland itself which we have not attemped to penetrate: it is made up of the covering Kamthis, which would have to be pierced before reaching the Barakars underneath, as a rule to depths ranging up to 300 feet, the strata themselves being often very hard and intractable. This depth at least is not overpowering; but even so, it is a question whether higher Barakars than those we have touched would be found.

The relation of the Kamthis to the Barakars in this area has always been looked on as one at least of overlap, if not of unconformity, Mr. Ball having had rather a strong leaning to the latter condition. I myself have only one section of what I can look on as showing unconformity, in the Jhajia Valley, and even it is obscured by what looks like a land-slip or slide of the Kamthi sandstone cliffs

bordering the river over the coal-measures in the bed. The whole facies of the occurrence of the one formation on the other, especially along the south-western edge of the field, has however gradually led me to concur in Mr. Ball's view of there being an unconformity, even if only a slightly discordant one, the difference in the general lie being on the whole only slight. If the unconformity exist, as we are more inclined to consider is the case, then the coal-measures, lying as they do in a flat basin, were planed down to a certain level before the deposition of the Kamthis: and I think I have every reason for considering that the Chowdibahal borings were commenced in very nearly, if not quite, the highest coal seams left by that planing. On the other hand, if the relation is merely that of overlap, these Chowdibahal seams are certainly the highest in the measures; and the Kamthis overlying them conformably, and therefore also in flat basonal form, will run somewhat to the deep and merely offer greater thickness for boring than I have suggested above.

The whole question about the plateau practically turns on any probability of the coal in the seams already tried improving to the deep: and on the thickness of overlying Kamthis to be pierced. The first is really after all a matter of opinion guided by experience; and I would put it this way: all the area of the plateau south of the line of railway can be very fairly judged of by what we know from the borings, and they are against any improvement to the deep thus far. The Baisandar Valley, that of Dulunga, and the denuded inlier of Barakars 8 miles north-west of Hingir give very much the same prospects for the seams to the deep on that side, for a considerable distance inwards from the edge of the plateau. There remains then an inner tract north-west of the railway, and west of Hingir, which is practically unworkable owing to the great thickness of Kamthis, and the extremely uneven and broken condition of that part of the upland.[1] We have the levels on the railway trace, which is run along the lowest part of the plateau, giving about 745 feet as the height of the upper part of the coal-measures at either edge of the plateau. The Hingir Road station is at 824 feet over sea-level: the top seam of coal in No. 2*a* of the Lillari Valley section is probably about 252 feet below the station: there being a rise up again of the dip from the axis of the basonal lie, which runs across about half-way between Chowdibahal and the station. This axis curves round to the north-west after this and runs up the middle of the plateau, so that the dip of the beds from the north-east or south-west on either side is towards that line. The coal seams will therefore deepen, or are at their lowest in the tract now under consideration. But the country gains considerably in elevation in this line of axis, going north-west from the line of railway,—so considerably indeed that at least 300 feet of Kamthis, and these often of the most intractable kind from their conglomeratic and ferruginously banded constitution, would have to be pierced before the Barakars could be touched. The conditions of the ground and the thickness of the upper sandstone are here the known factors; the probability of the coal being better underneath is more than ever a matter of opinion, and I am compelled to fall back on the simple belief that the probability of such a change is very small.

D. Pazar Valley.—On the northern edge of the Hingir-Raigarh plateau there

[1] Most inefficiently, and indeed incorrectly, delineated on the one-inch map.

is the rather extensive tract of Barakars watered by the upper tributaries of the Kelo and Kurket Rivers. It was, like all this part of the country, surveyed and reported on in a preliminary way by Mr. Ball; while I also had an opportunity of seeing its southern edge in one of my marches. Every now and then, promising-looking fragments of coal are picked up in the lower courses of these two streams; but they are always thin and are evidently derived from the 2 to 3 or 4-inch layers of good coal occurring so frequently in the thick seams of carbonaceous and grey shales. The only somewhat promising exposure met with by Mr. Ball is thus described by him:[1] "In the Bendia (near the mouth), which joins the Kelo at Gari, there is a considerable seam—

Ascending—Dip irregular, southwards 5°.

1. Carbonaceous shales, bedding irregular with some slight coaly layers towards base	4'—5' 0"
2 *Coal,* portions flaky, but for the most part burnable, much weathered	4' 10"
3. Parting, ferruginous sandstones	0 6"
4. Flaky *coal,* with carbonaceous shales excessively weathered and decomposed	

"I think it possible some good coal might be extracted from this seam. In its present decomposed condition even, it is easy to see from the manner of weathering that good or fair coal exists. The thicknesses given above do not hold for all parts of the seam."

Mr. J. G. Goodridge, C.S., Deputy Commissioner of Sambalpur, while on tour this year in that part of the country, picked up a large fragment of almost pure jetty coal, about 4 inches in thickness, from a shale outcrop. I have not much hope of this field, but even were the indications better, the field is not at all convenient to the line of railway, except perhaps on the western and eastern sides. On the latter there is an opening by the Baisandar Valley with a distance of about 40 miles to Rajpur, where it is proposed to have a station; but the country is decidedly more open to the west by the Kurket to its junction with the Mand, in which direction there would be about the same distance to the railway crossing of the latter river north-north-west of Raigarh. The southern side of the field is quite closed in by the rather lofty and scarped hilly masses of the Hingir plateau.

2.—Western Fields.

There still remains a great area of this Chhattisgarh coal-measure tract which according to some views presents rather more promising indications, and which will certainly have to be bored before any newer opinion can be formed on its capabilities. So long ago as 1870, Mr. W. T. Blanford brought the Korba Coal-field into rather favourable notice[2], and later still, Mr. Ball described the Mand Coal-field in some detail[3], while I have myself during the last two seasons' work

[1] Rec. G. S. of I., IV., p. 106.
[2] Rec. G. S. of I., III, p. 54.
[3] Rec. G. S. of I., XV., p. 172.

with the help of Sub-Assistant Hira Lal almost completed the survey of them and the intervening country, also of coal-measures.

A. Mand Valley.—This field is the nearer of the two to the line of railway, though it gives but a poor show of conveniently accessible coal outcrops. It is about 35 miles long from south to north, the southern end being about 10 miles from the proposed railway crossing of the Mand River at 14 miles west-north-west of Raigarh. Mr. Ball comes to the following conclusion, based on his survey of the eastern side of the tract:—"In reference to the economic prospects of this valley, I am distinctly inclined to regard them favourably. While it must be admitted that the majority of the seams which have been examined, as they happen to be exposed, do not disclose coal useful in quantity and quality, it should be remembered that the sections are much covered and the disturbance of the beds (excepting in the few noted instances) has not proved sufficient to give anywhere a complete section of the succession actually existing."

My own observations were confined to the western side of the valley, over which ground there are every now and then exposures of shales and coal in the stream beds, particularly in the Bijakharra, the upper course of which after leaving the hills runs for a mile and more in a foot and half band of coal occurring in a seven-foot seam of shales. Lower down this river there are outcrops of yet lower shales,—9 feet thick, with thin layers, over 18 inches—of coal. Traces of, I think, the same seams are met with in most of the watercourses and larger streams to the north, but all the seams are poor, and it is only at the extreme northern end about Amaldiha that any improvement is observable—as in the bed of the Gopal nala, which for several hundred yards is formed by a 2-foot seam of very good-looking coal, associated with a 4 to 6-foot band of shales.

Our combined observations tend to the conclusion that the northern half of this field bears a strong resemblance to the condition of affairs in the Rampur field: perhaps the coal looks a little better, as at Amaldiha; so that Mr. Ball may be considered to have formed about the most favourable view possible as to its capabilities. The worst feature about the northern end is, however, the wild jungly and out-of-the-way character of the country, making it so ill-suited for working the coal if it even exist in sufficient quantity and quality, and the getting it out of the place.

On the other hand, the southern end, though it be near the line of railway, does not show any good coal, and over a great part of it no coal at all. At the same time, the style of the rocks is promising; that is, the sandstones struck me as having a more decided Barakar facies of the right sort (as displayed for instance over the Wardha Valley (Chanda) and in the Godavari Valley,) being massive and thick-bedded, and of more uniformly pale grey or buff colours; while there is a fair display of underlying characteristic Talchirs on either side. At this end, there is a quadrilateral tract of some 32 square miles in extent of those sandstones which might, I am strongly inclined to think, yield better results than those hitherto attained. One bore-hole ought to help judgment as to whether there will be any use in going on further in that quadrilateral; while, in case of disappointment, a few holes might be run down higher up the valley to save any chance of finding coal within a reasonable distance of the railway.

B. Korba.—This town is about 26 miles north of the railway trace, and coal from any part of its field would have to be carried that, or a somewhat longer—up to 30 miles—distance. Its chief coal exposure has the advantage of having been reported on by Mr. W. T. Blanford, who was one of our most wise and cautious experts; hence it hardly befits me to offer any qualification on his opinion as to the merits of the field, except in so far as it may arise out of my subsequent closer survey of the ground. His report was written in camp (18th April) without having had his specimens of coal tested in the laboratory, but a list of their assays (dated May 9th) is appended to his paper; and that list goes far to show, not so much that the coal was on the whole less promising than he had anticipated, as that it is really after all very much the style of coal we have found in the Rampur field, and that a similar prevalence of thick bands of shales with, it may be, only thin seams of coal is the characteristic feature of the Chhattisgarh area. Of his assays, there is only one case—and that is in the lower two feet of a 4-foot band in the great 70-foot seam—of a decent coal, giving :—fixed carbon 60·5 per cent., volatiles 29·5 per cent., and ash 10 per cent. The average ash in his other samples is at the rate of 30·7 per cent. The finding of local developments of workable coal in this rather large area by boring, will be after all very much like looking for a needle in a bundle of hay. Hence the exploration must continue as hitherto a labour of trying likely places within reasonable reach of the railway. Failing that, the finding of coal must be left to the luck of private venture.

The great seam should, of course, be tried first on the selection of sites suggested by Mr. Blanford. Next, a locality or two, somewhat more out of the way, but giving a show of somewhat better coal, can be tried. The area of coal-measures stretching to the westward of the Hasdu River has been closely surveyed by Sub-Assistant Hira Lal, and he reports at least one rather good outcrop on the Aharan River near Sumedha, giving 5 feet 3 inches of coal, which yielded the following assay:—

Moisture	8·52
Volatiles (exclusive of moisture)	30·03
Fixed carbon	54·65
Ash	6·80
	100·00

There is no further exposure, so nothing can be said of the extent of the coal to the deep, or laterally.

Lastly, it is extremely difficult to form an estimate as to how long it may take to complete a sufficient exploration of these areas by boring; but as far as I can see at present, if the Mand Valley is to be abandoned early, that ground and the immediate neighbourhood of Korba might be examined during the coming season. On the least encouragement in the Mand, it would however be advisable to work slowly and gradually, thereby perchance necessitating the keeping of the work in that field for the season.

APPENDIX.

BORING JOURNALS OF THE ASSISTANT MINING ENGINEER, RAMPUR COAL-FIELD.

No. 1 Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil and clays	12
Hard red clay-stone	1
Coarse brown sandstone	2
Yellow clay	1
White mottled clay	10
Red mottled clay	2
Yellow mottled clay	2
Carbonaceous clay	2
" shaly sandstone	3
Yellow " "	1
Carbonaceous shale and sandstone	3
White sandstone	2
Carbonaceous clay and shale	8
Coal	2
Carbonaceous shale and sandstone	3
Coal	1
Carbonaceous shale and *Coal*	1
White shaly sandstone	1
Carbonaceous shaly sandstone	3
White sandstone	8
Yellow shaly sandstone	1
Carbonaceous shaly sandstone	4
" shale	2
Coarse shaly sandstone	2
Coal	7
Carbonaceous shaly sandstone	8
Shaly sandstone	8
Carbonaceous shaly sandstone	3
" shale	3
White sandstone	1
Yellow shaly sandstone	3
Carbonaceous "	8
" and shaly sandstone	9
Coal and shale	2
Carbonaceous shale and shaly sandstone	13
Coal	1
Carbonaceous shale and shaly sandstone	4
Coal	8
Grey shaly sandstone	2
Carbonaceous shale	2
" shaly sandstone	2
Carried over	156

No. 1 Bore-hole, Lillari Valley,—contd.

Strata passed through.	Thickness of bed, in feet.
Brought forward .	156
Carbonaceous shale	1
„ shaly sandstone	3
„ shale	2
Grey shaly sandstone	3
Carbonaceous shale and shaly sandstone	2
„ shale	7
„ shaly sandstone	4
Grey shaly sandstone	6
Coal	1
Grey shaly sandstone	2
Yellow „ „	2
Carbonaceous shaly sandstone	2
„ shale	2
Coal	4
Carbonaceous shale and *Coal*	3
Coal	1
Carbonaceous shale and shaly sandstone	11
„ „ and grey shaly sandstone	8
White sandstone	6
TOTAL .	225

Water tapped at 12 feet from surface. Work commenced 9th December 1884, stopped 5th February 1885.

No. 2 Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil and clays	12
Yellow coarse shaly sandstone	16
Yellow and red sandstone	4
Brown and yellow sandstone	5
Yellow sandstone	1
Brown „	7
Yellow and white coarse sandstone	8
Coarse red sandstone	18
Red clay-stone	4
Brick red sandstone	1
Red-sandstone	76
Light-brown sandstone	12
TOTAL .	159

Water tapped at 12 feet. Commenced 5th, abandoned 31st January 1885.

No. 2a Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Red sandstone	4
Brown sandstone	2
Yellow "	2
Light-brown sandstone	4
Dark-brown "	11
Light-brown "	16
Dark-brown "	9
Red "	41
Light-brown "	3
Red "	5
Red and brown "	1
Red clay-stone	2
Dark-brown and carbonaceous shale	9
Brown shaly sandstone	2
Blue and brown sandstone	1
Blue and grey "	1
Fine blue "	4
Blue and grey "	2
Slightly carbonaceous fine shaly sandstone	2
Carbonaceous shale	3
" " with a little *coal* and grey shaly sandstone	1
" shaly sandstone	1
" shale	2
Grey shaly sandstone	1
Carbonaceous shale	3
" shaly sandstone	12
" shale	8
" shaly sandstone	1
" shale	11
Grey shaly sandstone	1
Carbonaceous shale	8
Coal	6
Carbonaceous shale	6
Grey sandstone	8
Coal	1
Carbonaceous shale	7
Grey sandstone	6
Carbonaceous shale	5
Grey sandstone	6
Carbonaceous shale	2
Coal and shale	10
Shaly sandstone	3
Grey shaly sandstone	6
Carbonaceous shale	2
Coal	1
Carbonaceous shale	1
Grey shaly sandstone	7
TOTAL	250

Water tapped at 7 feet. Work commenced 16th February, stopped 1st May 1885, close of season.

No. 3 Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil	2
Yellow coarse sandstone	1
„ and white mottled sandstone	1
Brown sandstone	9
Red clay-stone	3
„ sandstone	63
Yellow „	2
Red „	32
„ clay-stone	1
Brown „	1
Dark brown and black shaly sandstone	4
Carbonaceous shaly sandstone, with a little *coal*	1
Brown sandstone and carbonaceous shale	3
Grey and brown shaly sandstone	4
Dark brown „ „	8
Hard light blue „ „	3
Carbonaceous „ „	1
Hard grey „ „	1
Fine blue and brown shaly sandstone	1
Carbonaceous shaly sandstone	2
„ shale	12
„ shaly sandstone	7
Grey „ „	4
Carbonaceous „ „	5
„ shale	11
Coal	6
Carbonaceous shale	1
Grey shaly sandstone	5
Carbonaceous shale	8
Coal	2
Hard grey sandstone	5
Carbonaceous shaly sandstone	6
Coal	3
Carbonaceous shale	6
Grey sandstone	19
Carbonaceous shale	4
Coal	4
Grey sandstone	36
TOTAL	287

Water tapped at 5 feet. Commenced 13th January, stopped 1st May 1885, close of season.

No. 4 Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil	5
Iron stone shaly band	1
Various clays	11
Carried over	17

No. 4 Bore-hole, Lillari Valley,—contd.

Strata passed through.	Thickness of bed, in feet.
Brought forward	17
Brown shaly sandstone	3
Carbonaceous shaly sandstone	3
Grey and brown shaly sandstone	1
Carbonaceous shale	2
„ shaly sandstone	3
„ shale	3
Coal	2
Grey shaly sandstone	4
Coal and shale	2
Carbonaceous shale	3
„ shaly sandstone	2
„ shale and grey shaly sandstone	5
White sandstone	14
Carbonaceous shale	5
Coal	6
Carbonaceous shale	4
„ shaly sandstone	7
„ shale	2
Grey shaly sandstone	2
Carbonaceous shale	3
„ shaly sandstone	4
Coal	2
Carbonaceous shale	3
„ shaly sandstone	1
Coal	1
Carbonaceous shale	13
„ „ and *Coal*	3
Coal	3
Carbonaceous shaly sandstone	6
Grey sandstone	18
White „	9
Carbonaceous shale	12
Grey sandstone	4
Carbonaceous shale	4
Coal	2
Grey sandstone	20
Carbonaceous clay	2
Grey sandstone	6
Carbonaceous shale	2
White sandstone	2
Carbonaceous shale	2
Coal	4
Grey sandstone	11
TOTAL	227

Water tapped at 16 feet. Commenced February 7th, closed May 1st, 1885, close of season.

No. 5 Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil	4
Various clays	10
Dark brown shaly sandstone and clay	1
Carbonaceous shale	6
Fine grey shaly sandstone	1
Carbonaceous shale	2
Slightly carbonaceous fine shaly sandstone	4
Grey shaly sandstone	1
Carbonaceous shaly sandstone	2
Grey and carbonaceous shaly sandstone	6
Coal	9
Carbonaceous shale	4
,, shaly sandstone	1
,, shale	1
,, shaly sandstone	1
,, shale	1
,, and grey shaly sandstone	4
White shaly sandstone	6
Carbonaceous shaly sandstone	5
,, shale and grey shaly sandstone	13
Grey shaly sandstone	1
Carbonaceous shale	5
Coal	1
Carbonaceous shale	6
Coal	4
Carbonaceous shale	12
Coal and shaly sandstone	1
Carbonaceous shale	1
Hard grey shaly sandstone	1
Coal	15
Grey shaly sandstone	8
Carbonaceous fine shaly sandstone	3
,, shale	10
Grey shaly sandstone	20
Yellow and mottled clays	3
Carbonaceous shaly sandstone	4
White ,, ,,	3
Grey ,, ,,	2
White sandstone	15
Carbonaceous shaly sandstone	1
,, shale and *coal*	2
Coal	15
Carbonaceous shale and *coal*	1
Grey shaly sandstone	5
TOTAL	221

Water tapped at 14 feet, which flowed over surface to the end. Commenced November 20th, 1885, stopped 30th January 1886.

No. 6 Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil	9
Soft brown sandstone	
" yellow "	
" brown " with clay	8
Brown sandy clay	3
Grey shaly sandstone	6
Brown " "	1
Carbonaceous shaly sandstone	4
Grey " "	6
Carbonaceous shale	9
" " and *coal*	9
Coal	7
Carbonaceous and grey shaly sandstone and *coal*	1
Grey and carbonaceous shaly sandstone	4
Carbonaceous shaly sandstone	8
Coal and carbonaceous shale	6
Carbonaceous fine shaly sandstone	5
Grey shaly sandstone	1
Grey and yellow sandstone	1
Grey shaly sandstone and *coal*	2
Grey shaly sandstone	2
Yellow " "	3
Carbonaceous shale	6
" " and grey shaly sandstone	3
" shaly sandstone	1
Grey shaly sandstone	50
Coal	1
Carbonaceous shale	4
Coal	4
Carbonaceous shale and *coal*	6
Coal	1
Carbonaceous shale and *coal*	4
Coal	6
Carbonaceous shale and *coal*	2
Coal	9
Carbonaceous shaly sandstone	2
" shale	1
" shaly sandstone	6
shale	2
shaly sandstone	4
shale	4
shaly sandstone	1
shale	1
shaly sandstone	2
Yellow sandstone	8
White "	12
Carbonaceous shaly sandstone	3
" shale	19
TOTAL	258

Water tapped at 26 feet. Work commenced 20th November 1885, stopped 29th January 1886.

No. 7 Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil and various clays	15
Vari-coloured shaly sandstones	16
Carbonaceous shale	1
Coal and carbonaceous shale	1
Carbonaceous shale	1
Coal	3
Carbonaceous shale	21
Grey shaly sandstone	5
Carbonaceous shale	4
Grey shaly sandstone	1
Carbonaceous shale	8
" shaly sandstone	8
" and grey shaly sandstone	10
" shaly sandstone	2
" shale	1
" shaly sandstone	4
" and grey shaly sandstone	15
" shale	4
" fine shaly sandstone	1
" shale	3
" " and *coal*	4
Coal	4
Carbonaceous shale	9
TOTAL	141

Water tapped at 15 feet. Work commenced 4th, and stopped 20th January 1886.

No. 8 Bore-hole, Lillari Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil and clays	6
Vari-coloured sandstones and clays	19
Slightly carbonaceous brown shaly sandstone	2
Carbonaceous shale	4
" " with a little *coal*	1
" "	8
" grey shaly sandstone	15
" shale	3
" fine shaly sandstone	10
Carbonaceous shale	8
" " and *coal*	9
" " and shaly sandstone	28
" " and *coal*	3
" "	10
Coal and carbonaceous shale	8
Carbonaceous shale	18
Coal	4
TOTAL	141

Water tapped at 20 feet. Work commenced on the 4th, and stopped 24th January 1886.

No. 1 Bore-hole, Oira Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil and various clays	18
Vari-coloured shaly sandstones	11
Carbonaceous " "	2
" shale	4
Coal	4
Carbonaceous shale	12
Coal	4
Carbonaceous shaly sandstone	3
Grey shaly sandstone	6
White fine soft sandstone	11
Carbonaceous shaly sandstone	2
White " "	4
White and yellow " "	1
Carbonaceous " "	2
" and grey shaly sandstone	2
" shaly sandstone	1
White shaly sandstone	4
Brown and soft shaly sandstone	1
White shaly sandstone	2
Yellow and black clay	1
White shaly sandstone	4
Yellow and white shaly sandstone	1
White sandstone	40
Carbonaceous shale	5
" " and *coal*	2
" shaly sandstone	1
Coal	2
Carbonaceous shale	4
" " and shaly sandstone	1
" shaly sandstone	2
" shale	24
" " and grey shaly sandstone	2
" shale	4
" " and *coal*	1
Coal	16
Carbonaceous and grey shaly sandstone	6
White sandstone	5
TOTAL	215

Water tapped at 25 feet. Work commenced January 28th, stopped 26th February 1886.

No. 2 Bore-hole, Oira Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil, sands, gravel, and clays	22
Carbonaceous and grey shaly sandstone	1
" shale	6
" shale and *coal*	1
"	9
Carried over	39

No. 2 Bore-hole, Oira Valley,—contd.

Strata passed through.	Thickness of bed, in feet.
Brought forward	39
Carbonaceous and grey shaly sandstone	6
" shale	2
Coal	14
Carbonaceous shaly sandstone	3
Grey " "	17
Carbonaceous shale	50
TOTAL	131

Water tapped at 9 feet. Work commenced February 7th, stopped 26th February 1886.

No. 1 Boring, Baisandar Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil and clay	3
Vari-coloured sandstones and clays in thin beds	37
Carbonaceous shale	1
Carbonaceous shale and grey shaly sandstone	4
Fine grey shaly sandstone	6
Black shale	1
Carbonaceous shale and a little *coal*	1
" "	9
Fine carbonaceous shaly sandstone	2
Carbonaceous and grey shaly sandstone	2
" shale	2
" " and *coal*	7
" "	2
Coal	6
Carbonaceous shale	63
" and grey shaly sandstone	7
Black and grey shaly sandstone	3
Carbonaceous shale	9
Coal	25
TOTAL	190

Water tapped at 13 feet. Work commenced 9th March, stopped 30th April, for close of season. Progress much delayed through hard stone and breaking and extraction of chisel.

No. 2 Bore-hole, Baisandar Valley.

Strata passed through.	Thickness of bed, in feet.
Surface soil and clay	8
Carbonaceous shale	1
Coal	16
Carbonaceous and grey shaly sandstone	1
Carried over	26

No. 2 Bore-hole, Baisandar Valley,—contd.

Strata passed through.	Thickness of bed, in feet.
Brought forward	26
Grey shaly sandstone	33
Carbonaceous shale	16
Slightly carbonaceous and grey shaly sandstone	34
Carbonaceous shale	16
Coal	6
Carbonaceous shale	
Coal	6
Carbonaceous shale	3
Grey shaly sandstone	3
Carbonaceous shale	4
Grey yellowish sandstone	9
White coarse "	3
TOTAL	103

Water tapped at 22 feet. Work commenced 11th March, and stopped 15th April, through breaking of chisel, which could not be extracted.

No. 3 Bore-hole, Baisandar Valley.

Strata passed through.	Thickness of bed, in feet.
Surface clays	2
Grey and carbonaceous shaly sandstone	9
Coal	20
Carbonaceous and grey shaly sandstone	3
Coal	4
Carbonaceous shaly sandstone	19
Slightly " " "	11
Carbonaceous " "	8
Highly carbonaceous shale	3
Carbonaceous shaly sandstone	3
Coal	10
Brown sandstone	5
Grey, mostly shaly, sandstone	30
White shaly clay and fine sand	9
White coarse sandstone	53
TOTAL	189

Water tapped at 5 feet. Work commenced 16th March, closed 1st May 1886, end of season.

Field-Notes *from* Afghanistán: (*No. 3*), Turkistán, *by* C. L. GRIESBACH, F.G.S., *Geological Survey of India* (*on duty with the Afghan Boundary Commission*).

Introduction.

The geological reconnaissance which I carried out in the spring of this year was limited to the confines of Afghan-Turkistán and the district of Bamián, which embraces the area north of the Tirband-i-Turkistán with the mountainous country stretching north of the Koh-i-Baba to the Oxus valley.

Geographical features.

The broad geographical features of Afghan-Turkistán are very simple. There are two distinct areas: a mountainous tract which occupies the southern part, and wide-stretching low lands which skirt the hills northwards. The mountain area consists of a succession of parallel flexures of varying widths which strike west to east or nearly so; generally speaking the folds increase in absolute height and decrease in width as they approach the main water-parting of Afghanistán. Along a line roughly defined as running south of Maimana to Sar-i-Púl, south of Balkh and Mazar-i-Sharif and thence south of Tashkúrghán to Badakhshán, an unsymmetrical flexure terminates the hilly tract of Turkistán. This flexure presents a steep side towards the north, where it disappears below the tertiary and recent deposits which form the great Central Asian plains.

Principal ranges.

The principal ranges thus formed are: the Koh-i-Baba, one of the links in the chain of the great watershed of Afghanistán. Part of the Davendar and Doshakh ranges of the Herat valley may be western points in this same chain; but which of the great anticlinals between the Davendar and the Koh-i-Baba is to be looked upon as the connecting link, I am unable to say.

North of this main line minor ranges run more or less parallel with the water-shed; of these is the Tirband-i-Turkistán with its eastern continuations. South of this range is a wide synclinal basin which belongs to the Murghab drainage. The structural prolongation of it may be found in a wide, undulating table-land, which occupies the space between the upper Balkh-ab (Rúd-i-Band-i-Amir) and the Kara Koh. I have not visited this area, but Captain the Hon'ble M. S. Talbot, R.E., describes it as a table-land, of which the eastern portion of the Kara Koh forms as it were a raised rim. The northern and north-eastern continuation of the Kara Koh forms a high chain against which a number of smaller ridges are ranged in parallel lines, both north and south of it. North of these auxiliary ranges extends a wide undulating synclinal basin with several areas of depressed table-lands; the northern termination of this basin is formed by the outer rim of the Turkistán highlands south of Mazar-i-Sharif.

Drainage.

The drainage of Afghan-Turkistán belongs to the Amú Dariá, or Oxus river, although only one of the streams of this part of Afghanistán actually reaches that river, namely, the Aksarai or Kunduz river, of which only a small branch of the upper portion belongs to Turkistán itself. All the other streams are either used up for irrigation purposes or lose themselves in the loess deposits of the Chúll, which forms the lowlands of Turkistán.

Principal rivers.

The Oxus rises in the Pamir and enters Afghan-Turkistán as a large river north-east of Tashkúrghán. Its valley varies greatly in width,—from about 30 miles near Tashkúrghán to over 80 miles near Akhcha and Kilif. It forms an extensive and in some parts very fertile alluvium, which presents some very interesting geological features.

The other rivers are: the Maimana river with its many tributaries, rising in the higher levels of the Tirband range; the Astar-ab and Sar-i-Pul system of drainage, which, flowing from the mountainous country of the eastern prolongation of the Tirband, loses itself in the plains of Shibirkhan and Akhcha; the Balkh-ab, known in its upper course as the Rúd-i-Band-i-Amir, comes from the Hazaraját and after a grand sweep from east to west, turns northwards and loses itself in the swamps west and north-west of Balkh; the Khulm or Tashkúrghán river, which rises north of the Kara Koh range and after a more or less northerly course is lost in the sandy wastes of the Oxus valley.

Only parts of the upper course of the Aksarai or Kunduz river are within the Turkistán and Cabul Hazaraját, north of the Koh-i-Baba; the Karmárd, Saighán and Bamián streams belong to its drainage.

River gorges.

One of the most notable features in the configuration of Afghan-Turkistán is the erosion, by the rivers, of deep gorges. I found that the inhabitants applied the word "dara" (valley) invariably only to defiles. Some of them are exceedingly narrow, like the Yakh-dara, between Deh-i-Faoz and Faúghan, south-east of Maimana, scarcely wide enough to admit an unladen mule being driven through without considerable difficulty. Many of these defiles surpass in picturesque grandeur anything I have seen elsewhere; as for instance the course of the Astar-ab below Faúghan, where the river flows in a narrow gorge, often not more than 30 yards wide and enclosed by vertical walls of limestone, some 1,500 feet sheer height above the stream bed. Most of the rivers flow from south to north and hence form transverse valleys through the ranges of Turkistán. They have eroded gorges where they cross anticlinals, and formed wider valleys with side-streams when on a synclinal.

Structural features.

System of flexures.

As already mentioned the Turkistán highlands consist of a succession of flexures more or less parallel to each other. Their structure is generally very simple and reveals the following facts: that (1) the lowest beds exposed in any of the sections, not only in Turkistán but as far as is known in Afghanistán generally, belong to the marine carboniferous series; (2) that the latter are overlaid comformably by a long succession of strata, partly marine, partly probably of fluviatile character, which form an unbroken and conformable series from the upper carboniferous to upper jurassic or neocomian age; (3) on the upturned and denuded edges of this base of older rocks upper cretaceous limestone of great thickness rests unconformably; (4) tertiary marine deposits and freshwater beds rest conformably on the upper cretaceous rocks; (5) that the general outlines of the present configuration of the country have existed since pliocene times, and that the force which has brought about the wrinkling of the older deposits is still continuing to add fold on fold in Central Asia.

The width of the belt of flexures appears to vary considerably, though the general lines of structure seem to remain more or less constant. So far as my observation has extended, I found that the belt of hills broadens considerably in the eastern sections.

Independent of minor folds between the lines along which the sedimentary zone has contracted, I believe the following great anticlinals can be identified.

4. Kaisar.	Almar.	Maimana.	Belcheragh.	Sar-i-Púl.	Albúrz.	Tashkúrghán.
3.	Painguzar.		Deh Miran.	Paisnah. (Astar-ab.)	Chahil.	Doab.
2. Main range of the Tirband-i-Turkistán.					Kara Koh range.	
1. Synclinal of the Upper Murghab.			Upper Balkh-ab (unexplored.)		Anticlinals of: d. Bajgah and Karmárd c. Dandan Shikan. b. Ak Robát. a. Palu Kotal.	

Great watershed of Afghanistán.

First group.

North of the system of great folds which form the watershed of Afghanistán is found a wide belt of shallow synclinals to which the Upper Murgháb basin belongs. The structure of the latter is explained by the exposures between Kushk and Bala Murgháb; the interior of the basin has remained a *terra incognita* to me. Eastwards of this region is the table-land of the Upper Balkh-ab, which Captain Talbot has visited; it is bounded north and south by the anticlinal rims of the Koh-i-Baba and the Kara Koh. The eastern margin of this depressed table-land is puckered into several very narrow anticlinals, across which the principal roads to Cabul lead; difficult passes and deep gorges traverse range after range between the Kara Kotal and Bamián. The headwaters of the Kunduz river rise in these folds.

Second group.

Immediately north of this belt, a series of wide arches and anticlinals are ranged in long lines across Turkistán. They form the most important land-marks in the physical geography of this country. I include amongst them the main range of the Tirband-i-Turkistán and the Kara Koh.

Third group.

A few well-defined and narrow flexures have been closely pushed up against the high anticlinals of the second group; their general direction may be traced from Painguzar, south of Almar, through Paisnah on the Astar-ab to the north side of the Kara Koh.

Fourth group.

To the fourth group I reckon the clearly-defined outer rim of the Turkistán highlands, *i.e.*, a more or less steep anticlinal which dips under a high angle below the tertiaries of the plains. The ranges immediately south of Balkh and Mazar-i-Sharif belong to it. Westwards

the Alburz and the long anticlinals of Sar-i-Pul, Maimana, &c., form a similar outer rim.

Between this range and the third group of flexures is a wide synclinal depression with areas of low table-lands in which streams have eroded deep ravines.

The greater part of these folds consist entirely of a thick mass of upper cretaceous formations. The great erosion which has taken place along the north slope of the Kara Koh and within the flexures of the third group has exposed the older base on which the cretaceous cap rests. Similarly north of the Koh-i-Baba, older rocks (carboniferous) have been laid bare of their covering of upper cretaceous limestone by denudation.

The Turkistán plains.

Against the last great fold which terminates the mountain area of Turkistán northwards, the tertiaries and recent deposits are ranged. North of the Maimana province they form low undulating loess hills, in which most of the streams which drain from the Tirband are lost. This widespreading loess area is known as the Chúll, and is found to gradually merge into the great plains south-west and south of the Oxus river, a great part of which is covered with modern aerial deposits.

Flexures in the Oxus valley.

There is good evidence that anticlinals are even now in course of formation within the recent deposits of the Oxus valley. I shall have to recur to this feature when describing the recent formations.

Stratigraphy of Turkistán.

I found the following formations represented in Turkistán and Bamián:

Age.	Formations.	Localities.
Recent . . .	Blown sands; alluvium of rivers; fans.	Chúll, Oxus valley, &c.
Sub-recent and post-tertiary.	Loess with interbedded clays, sandstones, and conglomerates.	Chúll; raised beds on the north slope of hills south of Balkh; patches within synclinals.
Pliocene . . .	Conglomerate and bright red and purple sandstones; bright red and green clays, with brown shales. *Planorbis* sp. *Helix* sp., and plant-remains. Gypsum veins.	Bamián and Mathár valleys; north fringe of anticlinals from Maimána to Tashkúrghán.
Miocene . Upper .	Light coloured shales, sandstones, and clays. Estuarine deposits with fish and crustacean remains. Plants.	Bamián and Mathár valleys; south of Tashkúrghán.
Miocene . Lower .	Sandstones and dark clays with marine shells. *Cerithium* sp.	Ditto ditto ditto.

Age.	Formations.	Localities.
Eocene?	Great thickness of light coloured sandstone and impure earthy limestone. *Exogyra?*	Mathár, Bamián.
Cretaceous — Upper	White chalk with flints. *Inoceramus* sp. *Exogyra* sp., many bivalves. Thick beds of white limestone with *Exogyra* sp. *Janira quinquecostata.*	Tirband-i-Turkistán range and anticlinals north of it. Main mass of the Kara Koh and folds between Saighán and Tash-kúrghán.
Cretaceous — Lower	Clays, shales, shell limestone, and beds with *Trigonia* sp.	Middle course of the Astar-ab and of the Almar stream.
Jurassic	Densely red grits and sandstone, shales with plant-remains; Trap. Dark bluish grey grits and sandstone; plant-remains. Ash-beds.	Upper Almar stream near Painguzar; Astar-ab below Paisnáh. Khoram-i-Bala north of the Kara Koh.
	Sandstone and black alum shales with plant-impressions; marine fossils.	Doab north of the Kara Kotal.
Upper Trias or Rhætic.	Light coloured sandstones and shales with *coal seams.*	Kotal-i-Sabz (north slope of Kara Koh), Shisha Alang.
Upper Trias — Upper	Great thickness of marine sandstone, limestone, and shales with *coal-seams.* *Schizoneura* sp., &c. Bivalves.	Chahil; Shisha Alang.
Upper Trias — Middle	Brown sandstones and shales with *coal-seams.* *Equisetites columnaris.*	Chahil, north slope of Kotal-i-Sabz.
Upper Trias — Lower	Marine sandstones and limestone beds. *Halobia lommeli.*	Chahil.
Permo-Carbon.	Altered shales (mica-schist, &c.) with graphitic and anthracitic seams. Clay shales with impure *coal.* The whole traversed by hornblendic granite.	Saighán; Ak Robát Kotal north.
	Coarse conglomerate in greenish matrix, altered by granite.	Palú Kotal and gorge; Ak Robát.
	Massive dark limestone with brachiopod casts.	Ditto ditto ditto.

DESCRIPTION OF FORMATIONS.

Permo-Carbon.

Locality.

The only section in Turkistán in which I have met with strata older than trias was within the greatly disturbed area between Saighán and Bamián. With few exceptions most of the beds in that section have been altered by contact with intrusive rocks, amongst which a hornblendic granite is most conspicuous.

Between Saighán (8050′) and the north entrance to the Bamián valley lies an elevated and undulating mass of hills, which consists of the Ak Robát synclinal (9800′) with the anticlinal of the northern Ak Robát pass (10750′) on its north side, and ending on its southern flank with two smaller anticlinals, which form the passes to Bamián, the southern Ak Robát pass, and the Kotal-i-Palú.

The main mass of the hills which close the Bamián valley on its north side, and over which the above passes lead, is composed of upper cretaceous rocks, which rest *unconformably* on the underlying older formations.

Exposed in the southern flank of the Ak Robát pass.

One of the branches of the headwaters of the Bamián stream run through a defile, which leads from the Ak Robát Kotal, south to the Bamián valley; this gorge has been eroded not only through the upper cretaceous rocks, which form the Pali Kotal east of it but also through the strata below, which belong to the carboniferous system.

Description of section south of Ak Robát. Fossils.

The prevailing rock seen on both sides of the gorge is a dark blue very hard splintery limestone, traversed by white calcspar veins; on the weathered surfaces of it I noticed badly preserved and distorted casts of brachiopods (*Productus ?*). The beds of this limestone formation dip under a high angle (from 50° to 70°) to north-west, and are overlaid a short distance higher up the valley by a semi-altered conglomerate or boulder-bed. A few irregular layers of a similar conglomerate are seen to alternate with the limestone beds below. It remains *in situ* a considerable distance up the south slope of the Ak Robát Kotal, and is apparently conformable to the dark limestone with brachiopods. The rounded boulders and pebbles of the conglomerate consist of limestone, and the matrix in which they are imbedded is likewise calcareous, and of a greenish colour. Near the southern entrance to this defile this section disappears below the upper cretaceous and tertiary formations of the Bamián valley.

Intrusive trap.

Large masses and dykes of trap traverse this section, and near the contact I found the limestone and conglomerate greatly altered. It has also penetrated the cretaceous limestone above and is therefore shown to be posterior to the upper cretaceous epoch. Similar traps are also seen in other sections in Afghanistán; the outburst may belong to the same which has broken through and altered the hipparitic limestone of Kandahar.

The kotal (pass) which leads to the Ak Robát synclinal is partly formed by upper cretaceous rocks, which rest unconformably on the older limestone and conglomerate series.

Section between Ak Robát and Saighán.

Between Ak Robát village and Saighán the older series crops up again and is strongly developed. The section runs from south to north and is formed of rocks closely resembling the limestone and conglomerate series south of Ak Robát. The succession of beds dips to north-west and is intersected by intrusive hornblendic granite, near the contact with which the sedimentary series is highly altered. I found in descending order:

Unconformably overlaid by cretaceous limestone.

7. Micaceous altered shales with thin *anthracitic* seams near the entrance into the Saighán valley, where the entire series is *unconformably overlaid* by the cretaceous limestone. 6. Mica schist and gneiss layers traversed by numerous quartz-veins.	Permo-carbon north of Ak Robát. Dip north-west.

Here a mass of hornblendic granite traverses the section, near which the adjoining strata are entirely altered into a semi-metamorphic series.

The granite encloses many angular fragments of rock, derived apparently from the neighbouring shaly group; in some places it becomes almost a breccia, cemented together by granitic rock.

5. Gneissic beds with mica schist. 4. Micaceous shales with several thin beds of *anthracitic coal*, partly graphitic. 3. Great thickness of altered shales or schists; micaceous.	Permo-carbon north of Ak Robát. Dip north-west.
2. Greenish altered conglomerate. 1. Massive dark limestone with brachiopod casts.	Carboniferous. Gorge south of Palú Kotal, both south and north of Ak Robát. Dip north-west.

Three distinct groups.

It will therefore be seen that the series consists of three distinct groups of rocks, which are in descending order:

3. Shaly group with *carbonaceous seams*.
2. Conglomerate.
1. Limestone (*Productus*?)

The whole succession of strata dips to north-west, where they disappear below the cap of cretaceous rocks. All three groups of rocks form one structural whole, conformable to and passing gradually from one into the other. The massive dark limestone with brachiopods in particular is closely connected with the greenish conglomerate above, with which it alternates partly. The dark limestone I may without risk identify and correlate with the carboniferous limestone, so largely developed westwards in the Herat province and Khorassan, and thus the greenish conglomerate will also have to be included in the carboniferous group.

Similarity of the Herat section with Bamián.

Near Herat[1] I observed an analogous section, although there the thickness of the entire series of beds is very much less than that of the Bamián rocks. The general character of the rocks composing both sections is very similar. On the north slope of the Davendar greenish beds with conglomerates and a thin coal seam rest

[1] Records Vol. XIX pt. 1, page 54.

conformably on true carboniferous marine limestones. At Bamián the conglomerate and the brachiopod limestone are even more closely connected, and cannot be separated from the carboniferous series.

Talchirs in the Herat section.

I expressed my belief last year that the greenish sandstones with conglomerate of the Herat province may represent the Talchir horizon of India, and if that view is correct, then the latter is of carboniferous age. I am still hoping again to traverse these rocks near the Hindu Kush range at some point where the alteration through contact with eruptive rocks has not quite obliterated all organic remains, and so may finally decide the question of age of the anthracite shales.

Links between palæozoic and triassic series hidden by cretaceous cap.

The continuation of older rocks towards the north and below the cretaceous cap seems likely, as is proved by the fact that at 27 to 30 miles north of Saighán middle triassic rocks crop out from under the overlying cretaceous limestone. Below the latter and in the belt between Saighán and Chahil I expect all the connecting links between the anthracite shales (3) and the middle trias will be found. It is even possible that these links may be exposed at some point where the denudation has worked through the covering skin of cretaceous rocks.

Permo-carbon age of anthracite shales.

This being the case both permian and lower trias are hidden, the former perhaps only partially. At present I must look upon the anthracite shales of Ak Robát and Saighán, connected as they are with the underlying carboniferous series,—as being passage beds between the carboniferous and permian.

Granite and trap intrusions.

The intrusions of the hornblendic granite north of Ak Robát and the trap of the Palú-kotal belong to a subsequent epoch and may possibly be of late cretaceous age, to which the granite intrusions of Kandahar belong.

According to former observers[1] a syenitic granite enters largely into the composition of the Hindu Kush range near the pass of Hindu Kush. It is very probable that the rock I observed south of Saighán is only a spur of the granite masses which have penetrated the limestone of the Hindu Kush.

From stray notes given by Drummond,[2] Lord,[3] and others who were in Afghanistan during our first campaigns in that country 48 years ago, it appears that a formation of schists, traversed by granitic veins and enclosing fragments of limestone, extends between the Hindu Kush passes and the Koh-i-Daman. Along the latter even the seams of graphitic coal are not wanting, and so one may assume that at least the older Saighán beds, *i.e.*, the palæozoic series, occurs also south of the Hindu Kush. The strike of the beds in that district is approximately from south-west to north-east, which is also the strike of the Paghmán range and its south-western continuations. Taking into consideration the report that coal-seams have been found near Ghazni, the inference may be drawn that

[1] Lord, P. B.: Journ. As. Soc. Beng. Vol. VII., 521—1838; and India Review, etc., III. 315—1839.

[2] Journ. As. Soc. Beng. Vol. VII, p. 521, and India Review, etc., Vol. III, p. 315.

[3] Journ. As. Soc. Beng. X, p. 74.

the Ghazni coal, if such exists, belongs to the same formation as the graphite of the Koh-i-Daman and the anthracitic coal of the Ak Robát pass, and Saighán. In that case we may fully expect to meet with the older coal-measures, equivalent to our best Indian horizon (Karharbari-Talchirs) within easy reach of our Indian frontier.

Trias and Rhætic.

Locality.

Most of the streams which denude the north slope of the Kara Koh and the anticlinals immediately parallel with it, have at several places entirely removed the thick cap of cretaceous limestone and so uncovered a series of strata which I found to represent horizons extending from the middle trias to upper jurassics. Most probably this is the case in all the deep valleys north of the Kara Koh range, but I have only been able to examine a few of them, in which, nevertheless, I was rewarded with good sections through the lower and middle mesozoic groups. I found the best sections in the Shisha Alang and Chahil (Chil) valleys, where both triassic and rhætic beds are exposed. The streams which drain these valleys rise on the north side of the Kara Koh, and run eventually into the Balkh-ab.

The area of triassic rocks exposed at Shisha Alang is quite detached from that of Chahil, that is, the intervening high ranges crossed by the Shaúbáshak and Bala Gali passes (8,800′ and 9,330′), are formed by upper cretaceous rocks which hide the triassic section below.

Section at Chahil.

The Chahil area exposes the lower strata of the upper triassic group of modern European geologists, or beds which closely represent horizons from the zone of *Halobia lommeli* to the plant-bearing Lunzer beds of the Alps. The section forms a wide arch, the beds of which dip generally south-west and north-east. Part of this arch is overlaid (near its highest point) by the upper cretaceous limestone of the Chaúli Khán. On nearer examination I found the Chahil section greatly disturbed and in some places crushed. But I was able to determine in general outlines the following horizons in descending order:

12. Grey and bright coloured sandstones, with shales and a few limestone partings. They weather nearly everywhere to a bright brown ochre colour, reminding me in that of the Himalayan trias. A few *thin coal seams* occur near the top. Lower down *coal* occurs at regular intervals of about 80 to 100 feet; several of these seams are upwards of 6 feet thick. Plant-impressions, mostly of stalks with some marine remains (bivalves), but in a poor state of preservation. Thickness not less than 1,800 to 2,000 feet.
11. Fine-grained greyish brown sandstone in thick beds.
10. *Coal-seam*; thickness 10 feet and quality apparently excellent.
9. Impure *coal*, with partings of bituminous shales and thin beds of ferruginous clays.
8. Thick beds of fine-grained brownish yellow sandstone with grey shales. *Equisetites columnaris*, Sternb.
7. Grey clay shales.
6. *Coal-seam*, thickness 1′ 6″ and very friable.
5. Brown shales with plant-remains.
4. Coarse grey sandstone and grit; fragments of plant-remains and casts of marine shells.
3. Gritty white sandstone, very friable and sandy, in thick beds containing marine fossils.
2. Same as 3, but alternating with friable light grey shales with bituminous layers, which yield a few fragments of plants.

1. Hard calcareous dark brown sandstone, containing numerous marine remains, amongst which *Monotis salinaria* and *Halobia lommeli* are very common. The lower part of this section, beds 1 to 11, cannot be less than 2,000 feet in thickness, and is probably much more.

Exposed in valleys of denudation only.

This section is only exposed where the upper cretaceous limestone has been completely removed by denudation; consequently the base and sides of the entire Chahil valley with the upper Chahil basin, including the steep south-west slope of the Sabz Kotal, are made up of folds of the triassic group, while the great mountain masses which crown the sides of this valley with inaccessible cliffs belong to the upper cretaceous limestone.

Dip and strike. Distribution.

The principal fold of the triassic series runs nearly due north and south, and at the northern end of the Chahil valley, where it forms a steep anticlinal, is dipping 80° east and about 60° west from its centre. The direction of the fold gradually bends to the south-east and the arch widens as the dip lessens. So east of the second village of Chahil on the right side of the valley I found the lower beds of the series (1 to 4) dipping about 50° north-east below the cretaceous rocks which form the Chaúli Khán peak. West of this same village rises the very steep and almost inaccessible left side of the valley where I found the upper beds of the series to dip about 55° to 60° west and south-west. The same beds form the lower slopes of the upper Chahil valley, left side, on which the third of the Chahil settlements has been built The steep cliffs on the left side of the valley, above the spot where the stream emerges from the old moraine which divides the basin, belong to the upper part of the beds 12 and contain numerous plant-remains.

The left side up the valley above the village of Chahil is not only very steep but where accessible almost entirely covered with loose debris from the cretaceous rocks above, so that I was not able to obtain a detailed section of the uppermost beds of the series.

The lower portion of the ascent to the Sabz Kotal is hidden under a thick deposit of glacial debris, and the triassic strata only become visible in the stream valley, where they show a dip of about 60° to south-west.

The thick coal-seam (10) with its adjoining strata is *in situ* in that locality, and may be traced for a considerable distance up the slope of the Sabz Kotal.

Last ascent of Sabz Kotal.

Near the last ascent of the Kotal the north-eastern shoulder of the anticlinal is seen to dip 40° to 50° north-east-by-east. The beds exposed belong to the upper part of the group and rest on the main *coal* seam (No. 10). I observed the following succession in descending order:

16. Grey and light coloured clays and clay shales with yellow ferruginous partings.
15. Whitish grey soft sandstone, very friable; weathers rusty brown.
14. Same as 16.
13. Whitish soft sandstone in thick beds.
12. Bad shaly *coal* 1′ thickness.
11. Brown fine-grained sandstone in thick beds.
10. Coal-seam, 10′ thickness (No. 10 in section).

The beds 12 to 16 represent the lowest portion of bed 12 of the entire section.

So far as I am able to determine in the field without closely examining the fossil contents of this locality, it appears that at least three horizons can be made out, which correspond with foreign zones.

Three horizons, comparable with foreign localities.

1. The beds at the bottom of this series represent a well-marked horizon, which occurs not only in several distant parts of the world, as for instance both in the eastern Alps, Transylvania and California, but also is well represented in the Himalayâ of Kumaon, Gharwâl and Spiti, and this portion of the Chahil section may therefore be identified with the lower horizons of the upper-trias.
2. The next higher horizon which contains plant-remains, amongst which *Equisetites columnaris* is most frequent, may be compared to the Lunzer beds of the eastern Alps, which also occupy a position over strata with *Halobia lommeli* and *Monotis salinaria*.
3. The lower beds of (12) contain plant-remains, amongst which a *Schizoneura* seems abundant. Whether these plants will be found to agree with any of the Gondwana species is impossible to say at present, but the group in which they occur have a strong resemblance to upper Barakars in lithological character.

It appears therefore that the section exposed in the Chahil valley must be placed in the upper trias as now understood by Alpine geologists; the lower portions of it seem to belong to the Hallstadt horizon of the Alps, which has been traced from Central Europe through Asia to California and New Zealand.

The upper portion of the Chahil beds is mostly plant-bearing, and yields characteristic upper triassic (Lunzer) forms, of which some are common in the eastern Alps and others have a strong likeness to middle Gondwana species.

It is clear from this section that the triassic rocks, in common with the upper palæozoic strata of Bamián and Saighán, have undergone crushing and disturbance long before the deposition of the upper cretaceous formations which rest unconformably on the former; I believe the lower-trias will be found below the enormous limestone cap of the Kara Koh and its southern extensions. Perhaps some of the deeper valleys, for instance the upper Balkh-ab gorge, may have cut through this overlying mass of younger rocks and may thus have exposed the most interesting of triassic strata.

Section at Shisha Alang.

The headwaters of the Chahar-Aulia stream, which unites with the Kashindeh valley some distance lower down its course, are made up of numerous small rivulets and springs which rise in the high regions on the northern side of the Kara Koh. They have excavated an area of about 20 square miles in the cretaceous limestone, and exposed the underlying folds of older rocks.

Beds in this section disturbed before cretaceous times.

The beds in this basin have been folded and crushed before the deposition of the cretaceous rocks, which rest unconformably on the former.

Strike.

The Shisha Alang triassic series forms an anticlinal whose axis has been bent into a horse-shoe shape, the toe of which points towards the south-west. Some of the higher portion of the anticlinal

has been denuded away, and I found, therefore, the oldest beds of the section exposed about half way between the southern entrance to the Said Dád Mirgánd gorge and the ascent to the Shaúbáshak pass, whereas the higher horizons of Shisha Alang are seen near the headwaters of the stream of that name and close under the high cliffs which enclose the Para Shaúbáshak.

Character of rocks at Shisha Alang.

The general character of the section is that of a succession of sandstones and shales with coal-seams, which contain chiefly land-plants, although a few marine remains (brachiopods) are also found in some of the beds associated with the former. There are also several horizons of concretionary limestone containing marine fossils only.

Resemble upper Chahil beds.

The lithological character of the group of beds is very nearly that of the upper portion of the Chahil section, and both seem to contain similar plant-remains. I believe therefore that the Shisha Alang rocks form simply a western continuation of the upper Chahil group.

Repetitions of coal-measures.

The remarkable feature of the Shisha Alang beds is a coarse, gritty, light grey sandstone, which contains fragments of plant-remains, besides a few marine bivalves. This sandstone forms well-marked divisions between the several groups of coal-measures, each of the latter being about 300 feet thick. I cannot say how many of such repetitions may exist in that area, as the beds are far too much disturbed to enable me to form an accurate estimate. But along the low ridge, which forms the right side of the main valley of Shisha Alang, I counted 7 separate groups of coal-measures, each of about 300 feet thickness, which, for this portion alone, would give 2,100 feet total thickness.

Thickness.

Similarity of groups of coal-measures.

There is a remarkable uniformity in the composition of these groups of coal-measures; the only difference seems to be the varying thicknesses of individual beds and coal-seams. The general lithological character remains the same,—in all cases showing a close likeness to middle Gondwana rocks. The shales are generally dark grey with particles of mica scattered throughout.

Details of section.

One of these minor groups of coal-measures north of Shisha Alang I found to dip 40° south-west and to be in descending order as follows:—

	Ft.	Ins.
14. Thick beds of coarse, gritty, grey sandstone with numerous fragments of badly preserved plant-remains and a few marine bivalves (*Ostrea* sp.)	60	0
13. Good *coal*	5	4
12. Bituminous clay	0	4
11. *Coal*	6	6
10. Coarse white calcareous sandstone in thick beds,—a few marine bivalves	50	0
9. Dark grey, micaceous shales, plant fragments	7	0
8. Fine-grained flaggy sandstone	8	0
7. Coarse-grained sandstone, divided by grey plant-shales, and alternating with them	40	0
6. *Coal*	6	0
Carried over	183	2

		Ft.	Ins.
	Brought forward	183	2
5.	Bituminous clay with ferruginous concretions	2	0
4	*Coal*-seam, divided by a few very thin partings of clay; the latter of from ½ inch to 3 inches thickness. Coal rather leafy. Total	12	0
3.	Bituminous shales	25	0
2.	Friable *coal*, with plant-impressions, consisting of closely packed leaves (*Schizoneura*, &c.,) alternating with seams of good black *coal*. Total	30	0
1.	Coarse calcareous sandstone in thick beds, much jointed.	80	0
	Total thickness	323	2

Further up the stream I noticed that the dip increased rapidly to 50° south-west-by-south. Several of the beds of shales yielded good specimens of plant-remains, which will have to be determined hereafter.

Marine fossils.

On the opposite side of this valley where the beds dip to the south-east at an angle of from 40° to 50° I found some brachiopods in concretionary nodules which occur near the base of No. 14, in a shaly bed; they seem to bear a close resemblance to upper triassic forms (*Rhynchonella semiplecta* of St. Cassian?).

Right side of valley.

The same succession of strata may be traced on the right bank of the principal valley of Shisha Alang, and there shales seem to predominate over sandstones. At the same time I found that the thicker seams of coal split up into numerous thinner ones, divided by bituminous clays and micaceous shales. As many as 18 or 20 separate seams may be seen within about 300 feet of thickness.

West of first village of Shisha Alang.

West of the first village of Shisha Alang the coal-series crops out again and shows a similar succession of dark grey Barakar-like shales and sandstones, associated with leafy coal-seams, the whole set of beds being enclosed between thick-bedded massive sandstone and grits.

Distribution of fossils in the groups.

I noticed that the sandstones yielded generally only marine fossils (mostly bivalves), whereas the shales and coal-seams contained numerous Gondwana plants.

Estimate of available quantity of coal.

If I assume the average thickness of the best coal-seam at 6 feet only, which could be worked over an area of 9 square miles in the immediate neighbourhood of Shisha Alang, I find that the available quantity of coal would be no less than 50 million tons. In this estimate I have left out of consideration the fact (1) that triassic coal-measures with large seams of coal are actually exposed over a large surface in the Chahil Valley and the north-west slope of the Sabz Kotal, and (2) that permo-carbon strata with anthracitic seams appear between Saighán and Bamián, and that therefore the conclusion is evident that the whole lower trias and permian strata, *i.e.*, the equivalents of our lower Gondwana series, must be buried below the upper cretaceous limestones of the intervening country. It is consequently almost certain that the entire northern Hazaraját is one vast coal-field, which is partially hidden by superimposed cretaceous limestone.

Jurassic series.

Rocks lithologically closely resembling the jurassic deposits of Khorassan and Herat crop out from below the cretaceous cap in several localities north of the Kara Koh and north of the Tirband-i-Turkistán.

Localities.

East of the triassic sections of Shisha Alang and Chahil I found the jurassic series in great force in the valley of the Doab stream, which rises west of Khorak-i-Bala on the slopes of the Sabz Kotal.

Valley of the Doab stream.

The ridge which forms the Sabz Kotal is formed by a crushed fold of upper triassic rocks, overlaid on each side of the pass by upper cretaceous limestone. The beds dip towards the south-east and disappear finally below the cretaceous *Exogyra*-limestone, which composes the east slope of the pass. Below this cap of younger mesozoic deposits the uppermost trias (with rhætic and lias?) is probably hidden, for I found the head of the valley of the Doab stream near Khorak-i-Bala occupied by formations which I believe to belong to the upper half of the jurassic series.

Sabz Kotal.

The section through these rocks near Khorak-i-Bala, as seen from the heights of the Sabz Kotal, is very clear. Successive belts of dark brown, bluish grey, and bright red rocks which compose the jurassic series are seen to dip at an angle of about 40° to 45° to the south, where they are unconformably overlaid by the white *Exogyra*-limestone of upper cretaceous age, which forms the steep scarp of the Kara Koh. These successive belts are traversed by a small stream, which joins the Doab valley from the right near the village of Khorak-i-Bala. To ascend the Kara Kotal I had to go up this side valley and thus traversed the upper jurassic series nearly at right angles.

Section of Khorak-i-Bala.

The left side of the valley near Khorak-i-Bala is formed by very friable dark grey to black alum-shales with a few badly-preserved plant-impressions. The shales weather on the surface and on the upturned edges to a bright rusty brown, and often show a bright coloured metallic lustre on their planes, derived from decomposed iron pyrites. The deposit seems to remain very steady in its lithological aspect, and is generally found at the base of the "red-grit group" wherever I have met with the latter. Along the north side of the range called the Koh-i-kat-i-Shamshir in eastern Khorassan, as far as Zorabad on the Hari Rúd, and again on the north slope of the Tirband-i-Turkistán, the character of this deposit is the same. I believe the horizon will be found to be middle oolite; certain it is that the shales rest conformably on deposits with recognisable lower oolitic fossils in several localities.

Dark alum-shales left side of valley.

Occurrence elsewhere. Age.

The shales dip about 40° south and below rocks which I believe to belong to the widely distributed "red-grit group" or upper jurassics; the passage from the shales into the overlying group is quite gradual.

Dip below "red-grit group"

Dark bluish grey sandstone; a local development of "red-grit."

The first division which I could distinguish in the "red-grit" group rests conformably on the dark alum-shales, and consists chiefly of a dark bluish grey sandstone and grit; the latter encloses grains of black limestone, probably derived from the carboniferous rocks south of the Kara Koh and Bamián. It appears to be a local development of the "red-grit group;" a rock closely resembling it I found last year near the Kala Sard, about 35 miles south-east of Máshhád. The blue grits are not sharply separated from the alum-shales below. Thin irregular layers of the latter occur between thick beds of the blue grey grits, and no doubt some beds of the latter will be found within the alum-shales; such I found to be the case along the north slope of the Baréli hill in the Koh-i-kat-i-Shamshir. The total thickness of the bluish grit and sandstone may be about 1,000 to 1,200 feet near Khorak-i-Bala.

Red grit.

It is concordantly overlaid by the typical red sandstone and coarse grits with strings of conglomerates which seem to compose the upper jurassics in every section which I have hitherto seen in the Herat province, Turkistán, or Khorassan. I found both in the bluish grey grits and the "red grit" some poor remains of plants, mostly only impressions of straight stalks and carbonized matter.

Thin coal-seam.

On the left side of the Doab stream, near the upper boundary of the alum-shales, I found an irregular and impure coal-seam of about 2 inches thickness.

The total thickness of the "red grits" is not seen, as it is discordantly overlaid by the cretaceous limestone of the Kara Koh

Jurassics of Doab.

Rocks of the same character and horizon may be traced along the Doab valley to the valley of the Tashkúrghán river; the Kara Kotal north of Doab presents steep scarps of upper cretaceous limestone towards the north, resting unconformably on the upper and middle jurassic groups. The sections south of the village Doab reveal the jurassic deposits dipping 35° to 40° west to south-west below the cretaceous limestone, and I found them to be composed of the following groups in descending order.—

3. Red grit group with volcanic breccia and tuffaceous beds.
2. Greyish blue grit and grey micaceous sandstone.
1. Dark alum-shales.

The red grit group (3) is of the usual and almost invariable character. I found also here some igneous beds associated with it, which consist of hard breccia and tuffaceous beds interstratified with the grit.

Below the "red grit" I found (2) grey micaceous sandstone and thick beds of greyish blue grits, alternating with friable black shales; this formation seems of very great thickness and composes all the lower slopes of the surrounding hills.

In lithological character this group is perfectly identical with the similar rocks which I saw near Khorak-i-Bala, about 10 miles west of Doab. Fragments of plants are very common in all the strata of group (2), but a bed of ferruginous, rather concretionary sandstone 1 mile south of Doab, yielded, besides numerous plant-fragments, some marine fossils of distinctly jurassic types.

North of Doab, on the way to Rui, I found the lower group (1) of the jurassic series, a grey sandstone with alum-shales containing a few plant-remains; they form all the lower slopes of the hills on both sides of the valley. The cretaceous limestone rests quite unconformably on the plant-bearing shales (1), and the grits and sandstones of groups (2) and (3) are wanting.

In the Tirband-i-Turkistán.

The general outlines of the geological structure of the Tirband-i-Turkistán range and its eastern continuations I have already given.

Mesozoic strata along third anticlinal.

The third anticlinal (see page 237) which runs almost unbroken from Painguzar to Doab on the Tashkúrghán river exposes lower and middle mesozoic deposits at several points below the capping cretaceous formations; I have described the older mesozoic and jurassic beds of the Hazaraját in the preceding paragraphs. The only other localities where I have noticed rocks older than cretaceous are situated south-west of Maimána and south-west of Sar-i-Púl.

Novel features.

In some respects these localities present altogether novel features, inasmuch as (1) any unconformity between the jurassic plant series and the cretaceous formations is doubtful, and (2) if such unconformity exists, then the overlap of the cretaceous formations must have begun during earlier neocomian times. I believe, however, that the apparent unconformity which I noticed south-west of Maimána can be explained differently, and that therefore the change of sea level which occurred after jurassic times did not affect the area north of the Tirband range.

South-west of Maimána.

The great anticlinal of Painguzar, 16 to 18 miles south of Almar, exposes some of the upper jurassic horizons; the overlying strata being a succession of deposits, amongst which I could determine both lower and upper cretaceous horizons.

Seeming unconformity above plant-shales

At first sight of the section an unconformity seems to exist between the red-grit group and the plant-shales below, but there are reasons which are against the assumption of any actual break between these two formations: (1) in sections west of this locality, *i.e.*, in Khorassan, the red-grit group and the black shales of the plant-group (jurassic) are always closely associated, and in fact alternate near the contact, and the same feature may be observed in all the eastern sections, as for instance near Khorak-i-Bala (page 248); (2), seeming unconformities are often observable where rigid thick-bedded formations resting on softer and yielding rocks have undergone lateral disturbance. In such cases, whilst the overlying rigid formations have only been bent into wide curves, the softer shales below have undergone greater crumpling and hence an appearance of discordance has been produced.

It is different with the unconformity between the older mesozoic formations and the upper cretaceous limestone in the Hazaraját; there the same very well-marked feature can be observed in every section, and the direction of the flexures of the underlying rocks differs entirely from that of the cretaceous limestone above.

The cliffs on the left side of the valley, between Painguzar and the Ziarat Khwaja Diwána, show the following section in descending order:—

Section of Painguzar.

Upper } Cretaceous group.
Lower }

Red-grit group with enclosures of gypsum; the passage from this into the overlying lower cretaceous beds is gradual

Bedding nearly horizontal near top of the anticlinal.

pushed over the beds below.

6. Dark shales with partings of ferruginous sandstone and strings of nodular clay iron ore The general character of this rock is completely that of the dark alum-shales of the Estoi hills.
5. Dark grey micaceous sandstone, weathers rusty brown; plant-remains.
4. Dark shales, same as 6.
3. Sandstone same as 5
2. Shaly sandstone
1. Thick-bedded grey sandstone.

Beds dip about 20° to 25° to north-west, the direction of the general dip a few miles further on.

In the Astar-ab.

Along the same flexure and nearly due east of Painguzar, I again met with upper jurassic rocks. The locality is near the villages of Paisnah and Deh-i-Surkh in the Astar-ab valley, about 38 miles south-west of Sar-i-Púl. The river makes a sweep to the east near these villages, and turns again abruptly north and north-east some 6 or 7 miles below Paisnah, where it cuts through the entire cretaceous and part of the jurassic groups along a line which now coincides with the crest of the third anticlinal (see table page 327) The flexure of the rocks has apparently taken place after the greater part of the valley had been eroded out of the mesozoic series, and in that particular locality the bend into an anticlinal naturally took place along the line of least resistance, where the thick mass of the upper mesozoic series had previously been cut through by the river. The strata are now seen to dip away from the centre of the valley—north and south.

I found the section a continuous one from the upper cretaceous (*Exogyra*-limestone) down to the black alum-shales with plant-impressions. There is not the slightest unconformity traceable throughout the series of strata either in this locality or in the transverse portion of the Astar-ab valley between Deh-i-Surkh and Turghan.

In all about 1,860 feet of strata are exposed below the upper *Exogyra*-limestone, of which about 1,050 feet belong to the red-grit group. The black allum-shales below are only partially exposed, their base being hidden below the alluvium of the Astar-ab.

Cretaceous series.

Change of physical conditions after jurassics.

With the close of the jurassic period seems to have begun the most marked change in the physical conditions of this part of the world; the jurassic seas began to shallow, and the greater part of Turkistán and Khorassan became most probably part of a continent which extended towards India. The forces

which are traceable to the present day in Turkistan folded and crumpled the *older and mesozoic formations until they were raised above the jurassic sea-level.* This shallowing and partial isolating of certain sea-basins may even be traced in the lithological character of the upper jurassics; the "red grit" which keeps wonderfully constant over the whole of Khorassan and Turkistán has most probably been deposited in a shallow and confined sea, and—as the gypsum layers in the sections of the south-western districts of Maimána show—possibly in land-locked basins.

Sub-aerial denudation during early cretaceous times.

The greater part of the upper jurassic rocks became subject therefore to sub-aerial denudation during early cretaceous times. Only near certain points along the cretaceous land deep bays existed; certainly in two localities, namely, in the sections west of Púl-i-Khatun in Khorassan and south-west of Maimána some marine deposits rest conformably between the upper jurassics and the upper cretaceous limestones which must have been laid down in such arms or firths of the lower cretaceous sea.

Lower cretaceous deposits.

The rocks which I believe to belong to this horizon in Khorassan I have described in former notes [1]; the Maimána province offers a very similar section through the lower cretaceous horizons, and I met the series fairly well developed in the Painguzar (Almar) neighbourhood.

Painguzar section.

Between the outer range of the Tirband, *i.e.*, the most northern flexure, and the synclinal of Farad Beg, extends the third great anticlinal (see page 327), which has been transversely cut through by the Almar stream, thus exposing the entire section. Both on the right side of the valley, east of Painguzar, as also immediately south of that village, the cretaceous series is seen to rest conformably on the red-grit group, and in spite of local crushing a fairly complete section can be obtained. I found the following beds in descending order:—

7. Thick-bedded whitish grey hard coral limestone with *Exogyra* sp.	Upper cretaceous.
6. Greenish earthy limestone with *Exogyra*; total thickness of these two groups about 2,000 feet.	
5. Considerable thickness of greyish beds inaccessible, but conformable on the beds below.	
4. Shell limestone, with numerous Foraminifera.	Lower cretaceous about 1,000 feet.
3. Do. do. containing *Trigonia* sp.	
2. Dark grey earthy shales.	
1. Greyish green soft sandstone in thick beds with concretionary layers, shaly towards the base.	
d. Red sandstone with gypsum beds.	Upper jurassics.
c. Parting of calcareous sandstone	
b. Coarse brownish grey sandstone.	
a. Red-grit group.	

Further eastwards and along the same flexure lower cretaceous strata are seen to rest conformably on the red-grit group and pass upwards in the upper *Exogyra* limestones.

[1] Records Vol XIX, pt 1, pp 59, 63

The succession of strata between Khamdán and Deh-i-Surkh in the valley of the Astar-ab is in descending order as follows: About 1,500 to 2,000 feet of upper cretaceous limestone with *Exogyra* sp. resting conformably on—

Section in the Astar-ab.

	feet.
5. Greyish earthy calcareous sandstone in thin flaggy beds	60
4. Light grey impure limestone with bluish green shaly calcareous sandstone	80
3. Same as (5) with *Exogyra* sp.	80
2. Rusty brown, coarse sandstone in thin beds with *Trigonia* sp. and alternating with shell limestone	250
1. Bluish green earthy shales and clay	80
b. Light reddish grit with shaly partings	200
a. Thin bedded shaly red grits	60
Total	2,810

passing gradually into and resting conformably on the red-grit group, which is here at least 1,000 to 1,200 feet in thickness.

The sections at Paingurar and near Khamdán will therefore be seen to be very similar and to correspond in general characters with the succession of beds west of Púl-i-Khatun, as shown in the range of the Takht-i-Gaúzak (see Records XIX, p. 63).

Maimána sections identical with Takht-i-Gaúzak.

I believe the beds 1 to 5 will be found to be of lower cretaceous age and to be identical with the light-coloured marls of Zulfikár.

It appears certain that none of these strata reach further to the east, as I have found everywhere in the Hazaraját and Afghan-Turkistán only upper cretaceous formations resting directly on older groups.

Upper cretaceous.

The greater part of the province of Maimána and of Afghan-Turkistán is covered with a wide-spread cap of upper cretaceous rocks.

With few exceptions the beds belonging to the upper cretaceous horizons consist of white thick-bedded limestones. Here and there a few layers of sandstone occur, which in that case often contain a few badly-preserved plant-remains. But by far the greatest thickness of the upper cretaceous formation is made up in ascending order of (1) hard white splintery limestones, (2) concretionary earthy white or brownish white limestones, occasionally dolomitic, (3) chalk with flints.

Rocks of the upper cretaceous.

The general character of the group seems the same in all cases, that is, it is formed in massive beds, the total thickness being about 1,800 to 2,000 feet. Towards the northern sections the thickness of this group increases, and I found that south of Balkh the total thickness cannot be less than 3,500 to 4,000 feet. In common with its overlying tertiaries it is folded and bent in wide anticlinals with occasional elevated table-lands between. The present rivers have excavated deep ravines and picturesque gorges through the rocks of this group, with steep, often vertical, sides. The general character of the group closely resembles that of the Quader of Bohemia, with which it shares approximately the same age.

Fossils.

The commonest fossils found in this group are *Exogyra* sp. and *Janira quinquecostata*, besides numerous others which have not been determined yet.

he fossil contents, not less than its stratigraphical position over lower cretaceous beds, assign an upper cretaceous age to the group. I believe that a more detailed study will possibly reveal that at least two European horizons are represented in it, but I have not been able to distinguish any divisions on my map.

Age, probably two horizons of upper cretaceous.

Exogyra sp. I found in all horizons of the upper cretaceous; but it seems probable that the lower portion of it is chiefly characterised by harder limestones, frequently a pure coral limestone, whereas the more earthy varieties seem to contain principally *Exogyra* sp.

The uppermost portion of the upper cretaceous is composed of white chalk and shell-limestone with flints, and contains *Inoceramus* sp., *Exogyra* sp., &c.; it forms about a third of the total thickness of the group. The best sections were found in northern Turkistán, between Haiback and Tashkúrghán, and south of Balkh, where the white chalk forms precipitous cliffs.

White chalk with flints.

The same horizon is found to form the upper portion of the cretaceous deposits between Chakau and Kalanau north of Kushk in the Herat province; it also caps the cretaceous series of Zulfikár.

Localities of the upper beds of the cretaceous west of the Tirband.

Tertiary formations.

The tertiary series of Turkistán is composed of the following groups:—

Composition.

Post-pliocene	Aerial and freshwater deposits.
Pliocene	Freshwater.
Miocene	Marine and freshwater.
Eocene (?)	Marine formations.

Of these groups only the post-pliocene deposits occupy large areas in Turkistán; the lower groups are confined to narrow strips exposed in deep folds of the upper cretaceous formation and in a few localities in the Oxus basin. In the highlands of Turkistán and the Hazaraját I have met the older tertiaries in Bamián and Saighan, where they are of small thickness, and along the northern edge of the hills of Turkistán, *i.e.*, resting on the chalk beds of the upper cretaceous series which dip below the plains south of Balkh and Mazar-i-Sharif.

Localities.

It is probable that during eocene times a large portion of the upper cretaceous sea began to shallow and here and there even to recede from its old coast-lines. The force which compressed the sedimentary formations into a narrow and folded belt north of the great Afghan watershed, dates from early tertiary times, when it had forced a great part of the area, now occupied by the Turkistán hills and the Hazaraját above sea-level. From that time date the extensive denudations which these tracts have been subjected to. In succession eocene and miocene formations, marine and freshwater were removed by subsequent and later

Changes of coast lines after cretaceous times.

erosions, until at the present day only a few remnants of the older marine beds are found compressed in elevated synclinals high up on the northern slopes of the Koh-i-Baba and Hindu Kush,—and the remainder of the area only shows the blown sands and fluviatile formations of much later date.

After the deposition of the lower miocene formations the sea seems to have withdrawn finally from the area now occupied by the high anticlinals of the Turkistán hills and retreated to the regions now occupied by the great Central Asian depressions. Lacustrine and fluviatile deposits began to spread over the gradually wrinkling surface of Turkistán and filled the wide synclinal basins with vast accumulations of sands, shales, and sandstone, which continue to the present day.

Section at Mathár.

At Mathár, south of the Kara Kotal, the cretaceous limestone with Exogyra sp. forms a wide synclinal trough, which encloses a fairly complete tertiary series, which I found in descending order to be:

9. About 150 to 200 feet of concretionary green clays with small ferruginous concretions and rust-coloured mud beds, containing fresh water gasteropods, partings of clay and ferruginous sandstone of bright orange colour. Towards the base some purple-coloured sandstone. The whole intersected by thin veins of gypsum.

8. 200 to 300 feet of chocolate-brown sandstone with shaly partings. This group shows fine mud deposits or clays towards the base, of yellowish-brown colour, containing fragments of vegetable matter and leaves; thin partings of pure light grey clay-shales. Towards the upper part gritty chocolate-brown clays and sandstone predominate, which, from thick banks in the centre of the group, changes into thin-bedded strata. A few thin partings of olive-green clays are very conspicuous in this mostly chocolate-coloured mass. — *Pliocene freshwater series.*

7. Great thickness of grey micaceous sandstone alternating with grey and green clays and chocolate-brown sandstone, which contains some gritty layers false-bedded.

6. Bright bluish green and yellowish brown clays with some sandstone beds. Contain plant-remains and freshwater shells; gypsum in layers and veins; great thickness.

5. Densely red sandstone with a few purple clay beds, towards the top great thickness of bright red sandstone and conglomerate, consisting chiefly of pebbles of cretaceous limestone cemented together by a red calcareous matrix.

4. Greenish dark clays and shales with partings of brown sandstone with concretionary structure. Thickness about 600 feet, with veins of gypsum and yellowish-brown earthy shales. The shales contain some fucoids and other plant-impressions, besides rather badly preserved remains of fishes and crustaceans. — *Upper Miocene (estuarine).*

3. Towards base of group 4, dark clays and soft clay shales predominate; the shales contain plant-remains and marine shells, *Cerithium* sp.; thickness about 500 feet. } *Miocene (marine).*

2. Bed of greenish clay at the base with layer of gypsum.

1. Thick beds of sandstone and shales with greenish earthy shales; *Exogyra* sp. } *Eocene? (marine).*

Rests conformably on upper cretaceous limestone.

Eocene group at Mathár.

With the exception of an *Exogyra* sp. I have not discovered any fossil remains in the lowest beds of the tertiary rocks. The passage from the upper cretaceous limestone of the anticlinal north of Bajgah to the miocene *Cerithium*-clays (3) is gradual and continuous, and I would naturally infer a representation of the eocene horizon in the section, even if eocene fossils had not already been described from that locality. I believe Captain Hay [1] describes eocene fossils from beds which rest on cretaceous rocks north of the Bajgah anticlinal, but unfortunately his paper is not available to me whilst I write this in the field.

Thickness.

In the Mathár valley this group is of considerable thickness, probably not less than 800 to 1,000 feet. The strata composing it are highly raised up, but perfectly conformable to the upper cretaceous *Exogyra*-limestone.

Eocene beds south of Tashkúrghán.

A very similar group of sandstones and shales lies between the upper cretaceous and the dark miocene clays, south of Tashkúrghán, where the tertiary rocks dip under a steep angle below the recent deposits of the Oxus valley.

Miocene.

Of great interest is the group of partly marine partly freshwater strata which rests conformably on the marine eocene beds at Mathár.

Marine clays. *Cerithium* sp.

Towards the top of the group of sandstones and shales (1) beds of a dark clay or clay-shales with subordinate sandstone beds appear, which finally merge into a thick group (about 500 feet) of dark friable clay-shales, which contain a few indeterminable plant-remains and some marine shells, amongst which a *Cerithium* sp. is the commonest. The form is probably allied to a species also found in the miocene salt-bearing group of the Adarbaijan province of Persia. The clay-shales are associated with gypsum layers and veins, which occur not only in this horizon but throughout the overlying strata.

Estuarine formation. Fish remains.

This group passes upwards into sandy shales, with concretionary brown sandstone and yellowish brown earthy shales. The passage from the *Cerithium*-clays into the group (4) is so gradual that I must assume the latter to have been deposited under estuarine conditions near a gradually shallowing sea. Of marine fossils I have found none in the group, but some plant-impressions, mostly fragments only, besides badly preserved fish and crushed crustacean remains are common. Veins and irregular layers of gypsum are found throughout the group, which is well exposed on both sides of the Mathár valley in which the tertiary series forms steep cliffs.

Freshwater series.

Group (4) is overlaid conformably by a series of beds, which all pass gradually from one into the other, and evidently form one structural unit. They are all freshwater deposits, probably of fluviatile origin, and remarkable for the bright deep red, brown or green colours prevailing.

The lowest stratum of this series is a coarse conglomerate which is chiefly made up of rolled debris from the cretaceous limestones cemented together by a red-

[1] Journ. As. Soc. Beng., IX, 1840, p. 1126.

dish calcareous matrix. It is well seen on both sides of the valley and near both ends of it, but perhaps may best be examined north-west of the village of Mathár, on the right side of the stream, where I observed it to rest seemingly conformable on the underlying upper miocene rocks. With this conglomerate and above it are thick beds of densely red coarse sandstones, alternating with a few thin earthy purple layers. The total thickness of this group is very great; at Mathár not less than 800 to 1,000 feet are exposed of it, but in other sections this figure is largely exceeded, and is most probably several thousand feet. The group is of wide-spread extent north of the central Afghan watershed, and may be seen in all sections below the more recent Chull deposits.

The groups 6, 7, 8, and 9, which form with 5 a structural whole, are, of course, not divided from each other in any defined manner, but pass from one into the other very gradually.

Tertiaries other localities.

It only remains to trace these groups in other localities.

Bamián Complete series.

In the Bamián valley itself the conditions are very similar; in a synclinal of upper cretaceous rocks, an apparently complete series of tertiary rocks is enclosed. I was unable to examine the Bamián section closely, as I was at the time suffering from severe fever, but fortunately Captain Hay (see footnote on preceding page) has given a description of that locality.

Oxus valley Lower tertiaries

The only other section where unquestionable lower tertiary rocks crop up is that of the Oxus valley, which presents altogether very interesting features.

South of Tashkúrghan

Conformably on the northern flank of the cretaceous anticlinal, south of Tashkúrghán and Balkh, I found the older tertiary clays and sandstones, more or less identical with the groups as described from Mathár, and they pass here also gradually into the bright red and green clays and sandstones of the lower pliocenes.

Re-appears on the Oxus.

The whole series dips under a gradually lessening angle below the aerial and fluviatile deposits of the Oxus plains to crop up again at their northern margin. The tertiary series seems strongly developed on the Bokháran side of the valley, but political reasons prevented my visiting the right banks of the great river. Between Kilif and Kham-i-ab the Oxus cuts an outcrop of the tertiaries and luckily exposes some of the marine miocene strata, and perhaps some portion of the group 1 (page 255).

Kilif. Shell limestone.

The cliff above the head-land of the Kilif ferry (Afghan side) is composed of sandstones with alternating shell-limestone, dipping at an angle of about 60° below the blown sands of the great plain which stretches south of the river. The shell limestone contains some *Ostrea*, *Pecten*, and *Bryozoa*, which all bear a strong resemblance to species figured by von Abich from the salt-bearing miocene of north-western Persia.

This complex of fossiliferous strata rests on irregular beds of white limestone, which forms the cliff west of the Kilif ferry; alternating with it and replacing the limestone laterally are large deposits and irregular masses of gypsum of reddish and black colour. The limestone yielded a few badly preserved fossils.

Limestone with gypsum.

The same gypsum group crops up again some 30 miles further west in the cliffs of Kham-i-ab on the Afghan-Bokháran frontier, where the formation forms a bold scarp facing north and gently dips below the recent deposits of the Chúll south of it. In one of the irregular layers of soft white limestone of Dev-Kala, a prominent hill south of Kham-i-ab, I found a few marine remains (bivalves) which await determination.

Kham-i-ab.

Fossils at Dev-Kala.

I venture to identify this group of rocks on the Oxus with the typical miocene formation of Persia and Armenia, which seems identical with the gypsiferous series of Loftus.

Identification with gypsiferous formation of Persia.

I am told that at the western slopes of the Koh-i-Tan in Bokhára, some 35 to 40 miles north of Khwaja Salar, some good rock-salt occurs in beds similar to the gypsiferous group of Kilif. The rock-salt is mined and largely used by the inhabitants on both sides of the Oxus. It is of a fleshy pink colour.

Pliocene formations in Turkistán

It remains now to describe the pliocene formations which occupy a very large area in Turkistán.

The Mathár section shows an apparently perfect conformity between all the strata composing the tertiary series; that, however, is not the case everywhere. Not only in the area between Mathár and the Oxus valley, but in all sections westwards of the Balkh-ab, I found the easily recognised bright coloured rocks of the pliocene series resting directly upon strata of the upper cretaceous group, and in most cases with apparent conformity.

After the close of the miocene period the conversion of a great part of the Central Asian sea into wide plains and isolated lake basins was finally accomplished, and the wrinkled and folded surface of marine deposits was gradually covered with a huge thickness of sandstones, clays, and sands during the pliocene and recent epochs

There is nowhere a marked lithological difference between the pliocene deposits and the recent accumulations of sands and gravels. The passage from the former into the latter is very gradual in most localities.

No marked lithological difference between the pliocene and recent deposits.

The lower beds of the pliocene formations are only seen near the contact with the cretaceous limestones, or where the beds have been sufficiently raised to bring them above the surface, and they therefore show in most cases the characteristics of great fans, accumulations of river gravels, and intercalated beds of sands and clays. The whole lower portion of these deposits is nearly everywhere of a dense brick-red colour, with occasional thin clay bands of bright olive green. This formation seems of a perfectly uniform character over the greater part of Afghanistán and Persia, and underlies everywhere the vast accumulations of blown sand of the Chúll which fringes the Turkistán low-lands.

Occurrence and composition.

The cretaceous limestones formed probably an undulating table-land in pliocene times, in the wide troughs of which the sandstone and gravels of that period were laid down. Subsequent wrinkling of this table-land into the compressed area we see now has also crushed the later tertiary beds into narrow synclinals. This feature can be observed in every case, where the tertiaries and recent formations are exposed.

Pliocene strata deposited prior to the general wrinkling of the Turkistán table-land.

The valley of the Belcheragh-Maimena[1] stream shows this structure exceedingly well. The greater portion of the synclinal along which the stream runs must once have been filled by pliocene gravels, clays, and conglomerates, which in this case were unconformable to the cretaceous limestone antiglinals on both sides of the valley. The force which completed the folding of the Turkistán rocks after the deposition of the pliocene gravels affected the latter also, and the section of these rocks near Katar Kala, between Maimena and Belcheragh shows now a high arch into which the pliocene rocks have been crushed, and which stretches across the synclinal trough of the valley. The present stream has since then worked its way through the great thickness of gravels and sandstone beds, leaving at some points only portions of the latter on each side of the valley. They seem now to dip below the cretaceous limestone at several points owing to the partial inversion the strata of the latter have suffered in folding.

Crushing of the pliocene deposits near Katar Kala.

The best exposures of the pliocene group may be seen along the northern margin of the Turkistán high-lands, *i.e.*, along the north slope of the last anticlinal. Densely red grits, conglomerates, and clays may be traced uninterruptedly from the western corner of the Tirband, near Bala-Murgháb, to Tashkúrghán in Afghan-Turkistán. The coarser deposits (old fans) of the group rest usually conformably on the cretaceous limestone below, and with the latter they have now been highly raised, and in some cases been bent vertically. Northwards the dip gradually lessens and apparently becomes nearly horizontal.

The northern margin of the Turkistán hills.

There seems to be no great lithological difference between the pliocene accumulations and the more recent deposits, and I believe the passage from one into the other is very gradual. The greater part of the recent accumulations are of aerial origin, and consist of unstratified loess deposits. I noticed similar masses of loess within the pliocene group, and I believe therefore that the physical conditions of this part of Central Asia have not changed materially since the close of the miocene times.

Physical conditions of Turkistán much the same since pliocene times.

Some of the smaller and isolated areas of pliocene deposits within the great synclinals of Turkistán have probably been laid down in lake basins and river valleys, and so no doubt were some of the lower parts of the pliocene gravels and conglomerates near the northern edge of the high-lands, where the drainage from the hills spread over the great plains. But even in pliocene times, as at the present time, the fine dust and sand borne along by the northern air currents used

[1] This name is distinctly written Maimena in Mr. Griesbach's manuscript, but it would seem to denote the same as the equally distinct Maimána of other passages. Available maps of that region do not afford means of correction. The accentuation is defective throughout.—ED.

to meet the river-borne deposits coming from the hills. The sections of the Almar, Maimána, and Astar-ab streams all reveal the same facts: a short distance away from the edge of the hills, unstratified and irregular layers of loess lie between distinctly fluviatile formations, until still further away the former assume larger proportions, and finally the whole assumes the unstratified appearance of typical loess, which forms the wide Chúll north of Afghan-Turkistán.

Had I only observed the red grits and clays of the pliocene along the southern boundary of the Chúll, I would most probably have looked upon them as being of more recent origin, but the sections of Mathár and Bamián seem to afford a key to a different interpretation. At all events the lower portion of this huge accumulation of conglomerates, sandstones, and loess must be of pliocene age.

Recent formations.

From the preceding section it will appear that the history of the pliocene epoch has been repeated during later times and is still being enacted at the present moment. There is practically no difference in the lithological character of the deposits of these eras. Now, as in pliocene times, huge fans are spread out at the points where the present rivers enter the open plains and finer deposits are laid down further away from the fans. Air currents, probably little changed in direction since later pliocene times, bring yearly vast quantities of fine dust and sand and spread them over the low-lands of Turkistán, in the thick deposits of which the streams lose themselves with few exceptions. The finer particles of this dust is borne further southwards by the hot-weather winds and so find a last resting-place on the high slopes of the northern anticlinals. North of the provinces of Maimána and Turkistán immense deposits of aerial formations extend—formations which date from pliocene times to the present day. Only the southern margin of these deposits belongs to Afghanistán; the remainder covers the greater part of Central Asia and forms the lower reaches of the Oxus with the Aral and trans-Caspian region.

Here also the separation of coarser sand from finer dust is apparent and produces land of quite different nature. The coarser sand falls to the ground first and composes the great Turkoman deserts. Further south the finer dust produces the steppes of Afghan-Turkistán, known as the Chúll, which is still partly irrigated and under the influence of a larger amount of atmospheric moisture, and hence generally covered with good grass. According to Richthofen's observations, who has studied the aerial formations and steppes of northern China, these last two factors—moisture and vegetation—caused the cementing together and partial change of the air-borne particles of sand and dust and so caused the formation of unstratified loess deposits which cover immense portions of Central Asia.

In connection with the recent formations there are chiefly two features which I will notice here; the first is the fact that the folding process is still active at the present time, and the second feature is the accumulation of vegetable matter in certain areas of the Chúll.

Recent flexures.

The first fact seems proved by two observations; (1), at all the points where the present rivers of Turkistán form high alluvial banks,—and this is the case along their lower reaches in the

plains,—it is plainly seen that the beds composing these deposits have undergone considerable disturbance. Near the northern margin of the high-lands, sands and gravels of the younger alluvial deposits are raised high up, in some cases nearly vertically; further away from, the older anticlinals the dip of the recent deposits flattens gradually and forms the plains of Turkistán.

(2.) The valley of the Oxus between Akhcha and Tashkúrghán is formed chiefly by extensive and probably very thick deposits of clays, gravels, and loose sandstone. Near the river, and forming a belt of varying width, thick waves of blown sand cover this base of fluviatile deposits. The latter has been formed by the Oxus with its tributaries, the present Khulm, Balkh-ab, Sar-i-Púl, and Maimána streams. At the present time none of the latter reach the Oxus itself, but lose themselves in, and are diverted by, a great swell in the ground which extends more or less parallel with and north of the edge of the hills, and north of the populated districts of the plains. Though I have not seen any section of this 'rise' or swell in the valley of the Oxus, I believe that it is the beginning of an anticlinal which has formed in comparatively recent times. The Oxus itself is a good illustration of the fact known as De Baers'[1] law, inasmuch as it steadily encroaches on its right banks, at the same time depositing detritus on its left side. The river comes in great sweeps from Badakhshan, diverted certainly here and there by far projecting ranges, but on the whole steadily pressing northwards and so removing material from its right bank. It therefore hugs the hills of Bokhára the whole way. If no other agencies were at work, the river, in its endeavours to transgress on its right banks, would have levelled the cliffs of Kham-i-ab and Kilif, instead of, as appears now, having cut off a corner of the miocene group which forms the Bokháran side. The dip of these miocene strata, not less than the partially raised recent alluvial accumulations near the latter, prove that the gradual bending of the tertiaries of the Oxus basin into an anticlinal is going on at the present time. The river is as it were flowing along the crest of a mountain range now in course of formation. Here denudation keeps pace with folding, and hence the excavation of the river channel between the cliffs of Kilif and Kham-i-ab.

I believe the swell mentioned above to be simply another line along which an anticlinal is forming at the present time. The gradually rising fold being parallel with the direction of the river has aided the exertion of the latter to encroach on its right side and so resulted in the Oxus being gradually forced over the miocene deposits of Kilif, into which the river eroded a channel, whilst the left banks continue to bend into a new flexure.

The lesser eroding power of the former tributaries of the Oxus in Turkistán could not keep pace with the steadily rising area of the new fold, aided by the accumulations of aerial formations which collect mainly along the northern curves of this flexure, and hence the streams have now been cut off from the Oxus and are mostly lost in the Turkistán plain or form irregularly shaped marshes.

The second feature which I observed in connection with the modern deposits of rivers seems to me of considerable importance in illustrating certain conditions under which carbonaceous deposits may have been formed. Afghánistán, especi-

[1] Bull. Acad. St. Petersburg II, 1860

ally the hilly portion of it, is remarkably poor in vegetation; its hill-sides are all but absolutely devoid of any. Trees are very few and far between, and grass exists only as separate tufts here and there. The lower slopes are generally well clothed with fine grass amongst which thistles and camel-thorn species flourish, and in some places altogether replace the former. The scorching dry winds of the summer soon dry every blade of grass and every single thistle, which after a time are reduced to more or less of a vegetable dust. The dry stalks and scrubby parts of thistles and camel-grass become now the sport of the wind, and it is not uncommon to see them accumulated into the shape of large balls or bundles careering over the dry surface of the hill-sides. Most of the smaller rivulets in the hills become quite dry during that season, and others are reduced to quite small runnels. In the spring, however, when the snow melts and tremendous thunderstorms break in the mountains, every little streamlet changes into a violent torrent, whilst the big rivers become altogether impassable, often for months. At that season the channels of all the hill streams, previously choked with vegetable dust and debris, are thoroughly cleaned out. So are the hill-sides and sloping plains, with the result that all this organic matter, representing more or less the entire vegetable growth of the preceding year, is washed down into the big rivers of Turkistán, which then are in flood. They are then more or less completely covered with a thick coating, a floating mass of vegetable debris, which consists chiefly of powdered and broken-up grass, some fragments of scrubby plants, such as thistles, and only a few broken branches or whole trees.

As I had to cross the principal mountain streams during my tour in the spring of 1886 I was forcibly struck with the fact that in a country so bare of vegetable growth as Afghanistán, every stream during spring-time was nothing but a sewer, in which almost everything that had grown the preceding year was washed down to the plains.

Had Afghanistán a climate more moist, and were the hill-sides covered with forests, the vegetable matter contained in the streams during spring-time would probably be very slight in comparison with what it is now. Grasses and annual plants would decay locally, more or less held together by tree-growths and the moister surface of the soil. As it is, however, the scorching and almost persistent winds which prevail in Afghanistán reduce every blade of grass on the hill-sides into a yellowish brown dust before the hottest days of the summer are over.

I was especially struck with this during last spring, when I crossed the Balkh-ab by the bridge at Akhkabrúk. A thunderstorm had broken in the hills to the south and the river came down a seething mass of chocolate-coloured liquid. Its surface was covered thickly with vegetable matter, such as I have described above. It was evidently the result of an extensive 'wash' of the whole hill-sides. So matted and thick was the mass of vegetable matter, that I noticed birds being able to alight on it, though it was floating all the time. With it, the water holds in suspension a large quantity of mineral matter and brings down large boulders. The noise of the latter as they rattle down with the current is sometimes quite deafening. I observed the latter fact when encamped at Haiback close to the Khulm river. It happened to come down in flood after a terrific thunderstorm, and the noise of the moving stones in its bed

was far exceeding that of the rushing torrent, and I could only liken it to the clash of machinery.

The mineral matter held in suspension falls gradually of course as the river proceeds, and the water will be almost free from such matter near the end of its course, where the river 'runs to earth' in the plain of Turkistán. Not so the vegetable matter floating along. Only a small proportion of it will find a resting place along the banks, as it is constantly again swept away by subsequent floods. Almost the entire sweepings of the hill-sides of the Tirband, of the Hazaraját, and the Turkistán high-lands generally find their way into the rivers and eventually get stranded in the reedy marshes of the Chúll, where in time the vegetable substance must form vast deposits in isolated areas.

Much of the water is used up for artificial irrigation, and with it no doubt a great deal of the vegetable matter helps to manure the lands of Turkistán; but in times before man helped to shape the course of natural events, the accumulations of vegetable deposits in the marshes of the Central Asian plains must have been very large and seems to me to explain the existence of coal-beds in formations which evidently were deposited in an area and epoch poor in vegetable produce, with a flora poor at least in species, if not in actual quantity.

Glacial formations.

There are no glaciers existent at the present time in Afghan-Turkistán. But that such filled some of the high valleys in former days, probably contemporary with the older alluviums, is proved by huge glacial accumulations in several localities which I have visited. Some of them seem so fresh and undisturbed that it is difficult to believe that behind them glaciers do not still exist.

High boulder bed terraces exist in nearly all the valleys, and some of them may be of glacial origin. Particularly well developed I found such in the valley of the Almar stream near Sarakh-dara and on the north slope of the Kara Galli pass south-west of Maimána.

I have however seen unquestionable glacial formations in several localities, as for instance in the valley of the Yakh-dara, west of Faúghan, near Shisha Alang and Chahil, at Karmard and other places.

In the Yakh-dara and at Chahil the deposits may perhaps be best studied. At both places the old glacier has retired, leaving its moraines perfectly undisturbed. At Chahil the valley is still blocked by the old end-moraine which forms a dam of boulders about one mile long right across the valley behind which the basin of the former glacier stretches, bounded on each flank by side-moraines. The floor of this glacial basin is covered with a fine mud, and half of it is occupied now by a deep lake. The drainage escapes through a narrow opening in the centre of the end-moraine.

Summary.

The sections which I examined this year are about midway between the Himalayan, Indian, and the Persian areas, and naturally show certain affinities with these regions.

Comparison with adjoining countries.

It appears probable that nearly all the horizons describ-

ed in this paper are represented in Persia also. With the exception of the formations enclosed between the carboniferous Productus-limestone and the upper jurassic beds, all or most of the horizons of the Hazaraját are also seen in the Himalayan or sub-Himalayan areas.

Eastern Khorassan and the Herat Province

As might have been conjectured, the likeness between the formations of eastern Khorassan and the Herat Province with Turkistán is striking, and would probably be found still greater, if I had had better opportunities of studying the former last year. The following table will show how the different horizons of these provinces may be correlated:—

Turkistán.	Herat Province.			Khorassan.
Blown sand of Chúll; alluvial deposits.	Alluvial deposits; blown sand of Herat valley and northern Badghis.			Blown sand, north-eastern Khorassan; alluvial deposits; salt-pans.
Upper pliocene and older loess of Chúll.	Loess of Badghis with beds of sandstone and conglomerates.			Loess deposit of lower Jam valley, Nishapur plain, &c.
Lower pliocene of Mathár (plant-beds).	Upper sandstone and plant-beds of Herat valley (Tirpúl beds); north of Shabash, Tirpúl, &c. Red and white clays with freshwater shells of Sakhra in the Murghab valley.			?
Upper miocene (estuarine) of Mathár.	Lower plant-beds of Tirpúl with gypsum. Red clays and grits with *Ostrea multicostata* of Badghis (Nimak-sar and Khwaja Kallandar).			?
Lower miocene of Mathár.				Sandstone with *Ostrea multicostata* Desh, near Khaf.
Eocene of Bajgah, Bamián, &c.	?			Nummulitic limestone with rhyolites, between Nishapur and Madan.
Upper cretaceous of Turkistán.	White chalk with fossils, south of Kila Nao. *Exogyra*-limestone of Darband, south of Bala Murghab.	White limestone with *Inoceramus crypsi* at Zulfikár and Ardewan pass.	Hippuritic limestone of the Doshakh range and Paira. Coral limestone of the Doshakh peak.	White chalk of Kelat-i-Nadri and Zorabad. *Inoceramus*-beds of Zorabad. *Exogyra*-limestone, Takht-i-Gaúzak near Púl-i-Khatun, Kelat-i-Nadri, &c.
Lower cretaceous (Astar-ab, upper Almar stream).	White sandstone and grits with *Ostrea* sp., and plant-remains of the Kashka Kotal. Shell limestone of the Band-i-Baba.	White marls and clay-shales with marine fossils of Zulfikár.		*Trigonia*-beds and shell limestone of the Takht-i-Gaúzak; white plant-sandstone of Kelat-i-Nadri.

Turkistán.	Herat Provinces.		Khorassan.	
	Red grits (with volcanic breccia).	Barchut range (Chasma Subz pass, Robat-i-Surkh pass, Ardewan pass, Kurukh, Davendar range, &c.)	Red grits	Kat-i-Shamshir (S. E. of Máshhád); Madan west of Nishapur; Firaiman S. E. of Máshhád Yaktán range.
Jurassic group of Astar-ab and north slope of Kara Koh.	Black shales (plant-remains).	Kurukh valley, Robát-i-Surkh pass.	Black shales (with fragments of plants).	Zorabad; Garm-ab (Kat-i-Shamshir range); west of Takht-i-Gaúzak.
	Brachiopod limestone.	Iaoza.	Limestone and shales (with marine fossils).	Gaukharchang pass (Burj-i-Kalij Khan).
Rhætic? of Shisha Alang.	Brachiopod limestone.	Kholi Biaz east of Herat.		?
Halobia lommeli group of Chahil, &c.	Plant-shales and sandstone. Green shales	Ditto ditto. Ditto ditto.	Green shales of Yaktán range and Dehrud pass.	
Lower trias and anthracite group (permian).	Green plant-shales with coal-seam.	Ditto ditto.		?
Carboniferous of Ak Robát.	Carboniferous Productus-limestone.	Robát-i-Pai; Doshakh range; Kholi Biaz.	Carboniferous Productus-limestone of Yaktán range, Dehrup pass, &c., &c.	

It will be seen that up to the close of the jurassic group the difference between the lithological characters of the various sections is not great. The carboniferous Productus-limestone was certainly laid down under purely marine conditions. From the close of the carboniferous to upper jurassic times a littoral character prevails in all the deposits from eastern Khorassan to the frontier of Badakshan, and I may conclude that, during permian times, the sea gradually became shallower, even leaving isolated basins and estuaries along the Perso-Turkistán tracts.

While the sea continued to retreat further northwards during jurassic and lower cretaceous times in the eastern portions of Turkistán, other parts of the old coast-line became gradually again submerged and the overlap of the sea reached its maximum extent in upper cretaceous times, when vast tracts of south-eastern Europe, Persia, and Afghanistán with Beluchistán, Sind, and the north-western margin of the Indian continent were covered by an ocean, which was most probably continuous over these areas.

From that time forward eastern Khorassan and Turkistán, and indeed the greater part of Persia, seems to have enjoyed much the same physical conditions. As my work in Khorassan and the Herat province was only of the nature of a reconnaissance, some blanks appear in the foregoing table, where probably whole

groups could be recorded if I had had opportunity of examining certain sections more carefully.

North-western Persia and the Elburz.

The literature which bears on matters relating to Persian geology is very large, but the only connected accounts which we possess, we owe to Abich,[1] Grewingk,[2] Loftus,[3] Blanford,[4] and Tietze,[5] and according to these authors it appears that the geological structure of northern and north-western Persia closely corresponds with that of Afghanistán.

From the upper cretaceous to the youngest formations the resemblance is very strong. The passage from the upper cretaceous into the nummulitics and lower tertiaries is very gradual, as Abich has shown for the north-western Persia. There are also miocene marine deposits, overlaid by great thicknesses of a marine salt and gypsum formation in which densely red rocks predominate, which formation (the gypsiferous group of Loftus) passes upwards into a freshwater group containing plants and mammalian bones, which stratigraphically corresponds with my pliocene freshwater group.

Along the entire Elburz range there appears below the upper cretaceous (hyppuritic) group and the true carboniferous (marine) rocks a great thickness of deposits, which contain in certain localities plant-remains of Gondwana types, and in north-western Persia some marine jurassic fossils in its upper beds. Coal-seams are found in many localities. I think it very probable that this series of deposits represents all the horizons which I found in Turkistán between the carboniferous and the cretaceous group. I hope to find the opportunity at some future time of examining this plant-bearing series of the Elburz and so establish its exact relations with my Turkistán sections.

India and the Himalayas.

Several of the groups of strata which I observed in Turkistán show close relationship to formations found in the Peninsula of India, the Central Himalayas, and Kashmir. All along the northern margin of Persia, through the Herat province and Turkistán, runs a more or less connected line of carboniferous rocks, containing marine remains common in the carboniferous beds of Europe. Formations of more or less identical lithological character and containing the same carboniferous fauna are found all along the Himalayan ranges from Kashmir to the frontier of Nepal. Several of the forms found in Kashmir and in the Perso-Afghan areas are identical, and it appears most probable that during carboniferous

[1] H. von Abich: Vergleichende geognostische Grundzüge der kaukasischen, armenischen und nordpersischen Gebirge. Mem. Acad. Sc. St. Petersb. Vol. VII. 359—536.

H. von Abich, Über das Steinsalz in russ. Armenien; pages 61—150.

Do. Beitr. zur Palæontologie des asiat. Russl.; pages 537—577.

Do. Eine Bergkalkfauna aus der Araxesenge in Armenien. Wien 1878 etc. etc.

[2] Dr. C. Grewingk, Die. geogn. und orogr. Verh. des nördl. Persiens.—Verh. Kais. min. Gesell. St. Petersb. 1853, p. 208.

[3] W. K. Loftus, on the Geology of portions of the Turko-Persian frontier, etc. Quart. Jour. Geol. Soc. 1855. Vol. XI. p. 247.

[4] W. T. Blanford, Eastern Persia. London 1876, pp. 437—506.

[5] Dr. E. Tietze, papers in Jahr. K. K. geol. Reichsanstalt 1875, pp. 129—140; 1877 pp. 1—6, p. 341—430; 1878 p. 169—206; 1879 pp. 565—658; 1881 pp. 67—130.

times these tracts were connected by sea. That connection seems to have continued, partly at least, up to later permian times, for in beds belonging to that epoch on the Araxes are found identically similar forms as in the beds with *Otoceras woodwardi* in the Central Himalayas, which I included in the lower trias at first, with which horizon they are structurally connected.

Whilst purely marine conditions prevailed from carboniferous to tertiary times in the Kashmir and Himalayan areas, the sea began to retreat gradually along the whole Perso-Turkistán line soon after the close of the permian epoch.

No marine beds seem hitherto to have been found in the Elburz lower mesozoic deposits; in Turkistán, however, I found several well-marked triassic and later horizons intercalated between beds of distinctly freshwater or estuarine character. Amongst them I recognized strata with *Monotis salinaria* and *Halobia lommeli*, both good upper triassic (Hallstadt) types. The horizon has been recognized by Stoliczka [1] and Lydekker [2] in the Spiti and Zanskar areas. I found it well represented in the Central Himalayas of Kumaon. In addition to this the Turkistán group contains also some Gondwana types of plants, which probably grew on the triassic land south of the Hazaraját, which may have been connected with the Indian Gondwana continent.

In the jurassic series I have only found one group of deposits which reminded me very strongly of a Himalayan horizon, namely, the Spiti shales. Lithologically the black alum-shales of Khorak-i-Bala and Doab in Turkistán and the Maimána province, no less than similar beds in Khorassan, seem undistinguishable from the Spiti shales, from which, however, they differ in their fossil contents. I found similar shales at the base of the cretaceous group of the Takht-i-Sulimán west of Dera Ismail Khan.

Cretaceous and tertiary.

The tremendous overlap of upper cretaceous deposits with the entire tertiary series of Turkistán seem rather to agree in their broad outlines with similar formations in Beluchistán, Sind, and the north-west frontier than with the Himalayas, with which I have not been able to correlate them.

The upper cretaceous rocks seem to have been laid down in a sea which stretched from the Adriatic to Afghanistán and round the north-western margin of India almost uninterruptedly, for both the lithological characters and the fossil contents of the upper cretaceous group seem very constant over the entire area. With eocene times some changes occurred, for the tertiary deposits of the Perso-Turkistán and Indian seas show some great differences. It may probably be found that the tertiary series of Sind and Beluchistán is perhaps structurally connected with the Perso-Turkistán rocks; there seems at least a similar succession of marine to freshwater series in both these tracts.

Shadian, near Balkh, 1st September 1886.

[1] Memoirs Vol. V. p. 44. [2] Memoirs Vol. XXII, p. 168.

Notice of a fiery Eruption *from one of the* mud volcanoes of Cheduba Island, Arakan.[1]

The following report, dated 1st of August 1886, from the Deputy Commissioner of Kyauk Pyu has been communicated by the Commissioner of Arakan:—

"I have the honour to bring to your notice that the Myooke of Cheduba reports that on the night of the 3rd instant at about 11 P.M. an eruption took place of one of the volcanoes in the Minbya Circle of the Island of Cheduba. The volcano, the fire burst from, is Nagabyinquin, called Nagapho (male). The flame rose to the height of 1,000 feet, the circumference or girth of it was about 500 feet; only lava and mud were thrown up, and it strongly smelt of petroleum. There was no damage done to cattle or human life."

The 'lava' means no doubt ejected fragments of the sedimentary rocks of the locality: see Vol. XI, p. 202.

Notice of the Nammianthal aerolite, *by* H. B. MEDLICOTT, *Geological Survey of India.*

Nammianthal is a village in the South Arcot district of the Madras Presidency, 6 miles north-east of the town of Tiruvannamalai, approximately at 79°-12′ E. Longitude and 11°-17′ N. Latitude. On atlas sheet No. 78 these names appear as Lamundel and Triomallee (old spelling). The fall occurred on the 27th January 1886. The stone was received in a single piece, but a portion had been broken off and about a fourth of the crust chipped away by the first official (a Police officer) who obtained possession of it. Its weight was 4,519 grammes: specific gravity 3·68. There was nothing remarkable in the shape: an irregular outline, with rounded edges and angles, and pitted over the surface in the usual manner. It is a rather coarse-grained oligosiderite, of very firm texture.

In forwarding the specimen the Collector of the district furnished the following account of the fall:—"One Ramasamy Goundan is said to have been in his field facing west, when he heard a loud report behind him (*i.e.* the east), and turning round observed the fall of the aerolite, which is said to have been accompanied by steam or smoke. The sky was cloudy at the time.

"The observer is reported to have become insane since the date of this occurrence. I have therefore been unable to gather any further information as to the circumstances of the fall."

Analysis of Gold-dust *from the* Meza Valley, Upper Burma, *by* R. ROMANIS, D.Sc., *Chemical Examiner to the Government of Burma.*

The Meza river is a western affluent of the Irawadi close to the town of Mayadoung, about 130 miles above Mandalay. The specimens were sent by the Deputy Commissioner of Katha, a station on the Irawadi some 35 miles higher up, and

[1] For previous notices see vol. XI, p. 188; XII, 70; XIII, 206,; XIV, 196; XV, 141; XVI 204; XVII, 142; XVIII, 124.

50 miles below Bhamo. The sample A was found at the foot of a range of hills 30 miles west of Katha; its composition was as follows:—

	Gold	87·66
	Silver	5·96
Gangue	Copper pyrites	1·95
	Silver	1·54
	Magnetite	0·32
	Quartz	1·09
	Loss on ignition	1·48

The specimen was in comparatively large irregular grains, with adhering quartz. The silver was partly alloyed with gold, partly in the residue insoluble in aqua-regia. Under the microscope I picked out an octahedral crystal of chrome iron and a grain of iridosmine.

The sample B was from the river sand; it was in small smooth grains. It contained little magnetite, but a comparatively large quantity of iridosmine. Analysis gave the following result:—

Gold	74·83
Silver	2·86
Platinum (with trace of iridium)	2·53
Iridosmine	7·04
Zirconia	7·08
Silica (by difference)	5·66

The iridosmine is known to the gold-washers as *shin-than* (clear iron), but they reject it as useless; so it seems likely that with due care a much larger proportion might be procured.[1]

In connection with the analysis of the gold, the following brief notice of the gold diggings in the Katha district may be of interest; it is abstracted from a report by Mr. H. M. S. Mathews, as published in the *Rangoon Gazette* of the 18th August 1886.

Five principal localities are noticed: (1) Ma-In-Shwomu, 70 miles north-west of Katha and 38 from Maing-Kaing on the Chindwin, several days by boat above Kindat; (2) Kaba Schwemu, 15 miles west of Wuntho; (3) Mauhaing Schwemu, 25 miles west of Manteit; (4) Ko-nan-yua, 20 miles north-west of Manteit; (5) Nanka Schwemu, west of the Mu river and on the same parallel as Wuntho. There are old workings in the Katha district itself, also in the independent country north of Ma-In.

There are three different methods of working:

(1) Shallow channels are dug in the gold-bearing ground, with deeper pools at intervals to serve as catchment basins. Water is then conducted into the channel from the nearest hill stream. After a few hours the water-supply is diverted and the water baled out of the basins, the silt collected in these being carefully washed for gold dust.

(2) By washing the silt collected during the rains in deep catchment drains, sometimes a mile and a half long, and generally the common property of a village. They yield from 5 to 20 rupees weight of gold in the season.

[1] For a notice of iridosmine from the stream gold of Upper Assam, see a paper by Mr. Mallet in the Records for 1882 (Vol. XV, p. 53).

(3) By mining the auriferous layers in the deep alluvial deposits. The layer is generally a span or less in thickness of dark sandy pebbly soil overlaid by a red layer of similar composition, which is again overlaid by ordinary loam, from 5 to 20 cubits in depth. In the dry weather drifts are driven from the bank of a stream on the outcrop of the gold-layer. At intervals of about 7 or 8 cubits a shaft is sunk down to the drift, apparently to secure escape in case of a fall of earth; the drift is then continued in the most promising direction. The earnings are very uncertain: from Re. 1-4 weight of gold to only 4 annas weight in a month. At the diggings the gold is valued at about Rs. 20 per rupee weight; at Katha the price is 20 to 30 Rs.

The gold-seekers are principally Kado Shans, *i.e.*, half-bred Shan Burmans; they work for two or three months in the year, and for the rest as ordinary cultivators. The workings are said to have been carried on for 300 years. In 1882 the Burmese officials were expelled by the Wuntho Chief who holds the country still.

ADDITIONS TO THE MUSEUM.

FROM 1ST JULY TO 30TH SEPTEMBER 1886.

'Dhobi's earth,' sand with carbonate of soda, locally used in washing clothes, occurs in patches among the low sand dunes on the shore of the Godavari delta; and some sulphurous earth, from the Godavari delta. PRESENTED BY MR. J. VANSTAVERN.

A piece of orpiment from Chitral, from hills north-west of Killa Drassan.
PRESENTED BY DR. GILES, GILGHIT MISSION.

Cobalt ore from Babai, south of Khetri, and slag from old disused copper mines, 20 miles from Babai near Dhanaota, about 1 mile north of Udeypur, a village in Jeypore.
PRESENTED BY DR. J. P. STRATTON, POLITICAL AGENT, JEYPORE.

A collection of minerals about 42 varieties, and 3 specimens of *Eozoon canadense*, from Canada. PRESENTED BY SIR J. WILLIAM DAWSON.

Specimen of gold dust from river sand, from Meza Chyaung.
PRESENTED BY DR. R. ROMANIS, CHEMICAL EXAMINER, BURMA.

A slab, 18 inches square, of red marble, cut and polished, from Jeypore, Rajputana.
PRESENTED BY THE JEYPORE MUSEUM.

The nearly entire meteorite that fell on the 27th January 1886, at Nammianthal village, 6 miles north-east of Tiruvannamalai town in South Arcot, Madras, weight 4519 grammes. SENT BY THE COLLECTOR OF SOUTH ARCOT.

Nineteen specimens of minerals from German localities.
BY EXCHANGE, FROM THE JENA UNIVERSITY MUSEUM.

ADDITIONS TO THE LIBRARY.

FROM 1ST JULY TO 30TH SEPTEMBER 1886.

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BACKHOUSE, *James.*—On a mandible of Machærodus from the forest-bed. With an appendix by R. Lydekker. 8° Pam., London, 1886. R. LYDEKKER.

BRONN'S.—Klassen und Ordnungen des Thier-Reichs. Band VI, abth III Reptilien, lief. 50-53. 8° Leipzig, 1886.

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BROSSARD, *E.*—Essai sur la constitution physique et géologique des régions méridionales de la sub-division de Sétif (Algérie). 4° Paris, 1866. H. B. MEDLICOTT.

BURMA.—Papers on the Geology and Minerals of British Burma, reprinted by order of C. E. Bernard, Chief Commissioner. 8° Calcutta, 1882.
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BURNES, *James.*—A narrative of a visit to the Court of Sinde; a sketch of the history of Cutch from its first connection with the British Government in India till the conclusion of the treaty of 1819; and some remarks on the medical topography of Bhooj. 8° Edinburgh, 1831.

CASTILLO, *Antonio del*, and BÁRCENA, *Mariano.*—Antropologia Mexicana. El Hombre del Penon. Noticia sobre el hallazgo de un hombre prehistorico en el Valle de México. 8° Pam. México, 1885. M. BÁRCENA.

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„ Review of the vertebrata of the cretaceous period found west of the Mississippi river. 8° Washington, 1874. H. B. MEDLICOTT.

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DELGADO, *J. F. Nery.*—Sobre a existencia do terreno siluriano no baixo alemtejo. 4° Lisbon, 1876. GEOLOGICAL SURVEY, PORTUGAL.

„ Relatorio da Commissao desempenhada em Hespanha no anno de 1878. 4° Pam., Lisboa, 1879.
GEOLOGICAL SURVEY, PORTUGAL.

„ Note sur les Échantillons de Bilobites envoyés a l'exposition géographique de Toulouse. 8° Pam., Toulouse, 1884.
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FISCHER, *Paul.*—Manuel de Conchyliologie. Fasc. X. 8° Paris, 1886.

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